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THE COST-EFFECTIVENESS OF STANDARDIZATION FOR HULL, MECHANICAL, AND ELECTRICAL EQUIPMENT

April 1978

Prepared for
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
STANDARDIZATION BRANCH (SEA 605)
WASHINGTON, D.C. 20362
under Contract N00140-77-D-0417

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ABSTRACT

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This report presents an overview of the Navy ship standardization program, the development of a standardization life-cycle-cost model, standardization-related work tasks, and a life-cycle-cost comparison of the use of standard and nonstandard HM&E components and equipments in different complexity categories. The results provide examples of reduced life-cycle costs achieved when a standard component or equipment is utilized.

SUMMARY

This study established a life-cycle-cost approach to determining the cost-effectiveness of the Navy shipbuilding standardization program for hull, mechanical, and electrical equipment. A standardization life-cycle-cost model was developed to determine the life-cycle cost and the cost differences incurred when a nonstandard rather than a standard component/equipment (C/E) is procured and supported throughout its inventory life. Cost elements making up the model are Government Program Management, Prime Equipment Acquisition, Initial Support Acquisition, and Support. Cost factors contributing to the life-cycle cost were associated with each of these cost elements, and input data were collected through discussions with Navy offices and commercial shipbuilders. In addition to offices in the Naval Sea Systems Command and Naval Supply Systems Command in Washington, D.C., the Navy Ships Parts Control Center at Mechanicsburg, Pennsylvania, and three Supervisor of Shipbuilding field offices at Newport News, Virginia, Pascagoula, Mississippi, and Seattle, Washington were visited. Meetings were also held with the Defense Logistics Agency because they support some Navy C/Es. Cost and other standardization-related data were collected from the following shipyards: Ingalls Shipbuilding, Newport News Shipbuilding, Lockheed Shipbuilding, and Todd-Seattle Shipbuilding.

The cost model was exercised, and cost differences between nonstandard and standard C/Es from selected representative categories of varying complexity were identified. Significant increased life-cycle costs for the nonstandard C/Es were found to be in the Prime Equipment Acquisition, Initial Support Acquisition, and Support cost elements. It was concluded that the life-cycle-cost difference resulting from these elements is the result of the difference in requirements in Production Test and Evaluation between the nonstandard and standard C/E and the associated cost of entering a new Allowance Parts List (APL) and National Stock Number (NSN) into the Navy supply system, including the associated supply system management costs. Also contributing was the acquisition cost of required documentation for the nonstandard C/E. A cost-sensitivity analysis was conducted on the cost inputs to determine their contribution to the total life-cycle cost. Cost inputs that have the greatest effect on the increased life-cycle cost resulting from the introduction of a nonstandard C/E are:

- Number of new NSNs of primary equipment and annual NSN maintenance cost

- Technical data acquisition, reproduction, and distribution costs
- Test documentation costs and costs associated with performance of tests

The cost for maintaining and administering the Navy shipbuilding standardization program was treated as a program overhead cost. It was prorated over an averaged number of APLs for a representative 12 year life cycle. This overhead cost was found to be insignificant when compared with other life-cycle costs investigated.

The following conclusions were reached as a result of the study:

- Standardization of Hull, Mechanical, and Electrical components/ equipments is cost-effective over the entire life of a ship. Representative savings that could be realized range from $4,800 to $1,000,000 per C/E, depending on the complexity of the C/E being considered.
- Estimates of the cost of introducing a nonstandard C/E into the supply system based only on the related number of new NSNs will not provide consistently accurate cost data. Introduction costs can be accurately determined only if realistic life-cycle-cost data are provided on the specific C/E under consideration.
- Current contract clauses do not require that life-cycle costing be used to assist in selecting C/Es.
- The standardization life-cycle-cost model developed is limited in the area of cost of associated spares. It does not recognize the varying effect that increased population of unique C/Es has on spares requirements.

On the basis of the study conclusions, the following recommendations are offered:

- The incentive or penalty associated with the introduction of a nonstandard C/E should not be based solely on the number of new NSNs in the APLs for the C/E or the percent of standard C/Es. It should be based on the difference in life-cycle cost associated with a nonstandard C/E in comparison with a standard C/E of identical form, fit, and function, and with differences in population considered. This will allow the incentive or penalty to reflect the new increase or decrease in life-cycle cost to the Navy. Life-cycle costing should be used in the selection process, and it should be contractually required.
- Decisions on the use of a specific standard or nonstandard C/E are made at the Shipyard/SUPSHIP level. It is important that the required level of information be provided to these activities to allow them to make the best judgment in support of the actual shipbuilding contract requirement. Life-cycle-cost guidance should be provided at this level.

- Costs associated with establishing and maintaining a supporting inventory are major contributors to the overall life-cycle-cost difference between nonstandard and standard C/Es. Additional work is necessary to develop more sophisticated cost estimating relationships for the standardization life-cycle-cost model. Field experience with the model is required. Further studies, including review of applications, should be conducted to refine the standardization life-cycle-cost model in order to increase its effectiveness.
- This study evaluated the life-cycle-cost savings for HM&E equipments only. Further studies should be conducted to expand the application of the model to other than HM&E equipments.

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CHAPTER ONE

INTRODUCTION

1.1 OBJECTIVE

The overall objective of this study was to determine the value to the Navy of standardizing HM&E (hull, mechanical, and electrical) equipment and the extent to which HM&E equipment standardization is cost-effective throughout a ship's life cycle. Specifically, this study was to identify the difference between the life-cycle cost (LCC) of introducing and supporting a new equipment or component and the LCC of using one that is already available and in service with the U.S. Navy. This effort was conducted for the Naval Sea Systems Command Headquarters, SEA 605 (Standardization Branch), under Contract N00140-77-D-0417.

1.2 BACKGROUND

Standardization is generally conceded to be cost-effective, although this benefit is usually considered in qualitative rather than quantitative terms. Considerable information and many directives have been produced to address the various types of costs, savings, and risks inherent in standardization programs. However, the few examples of actual dollar savings identified have been limited to particular aspects of standardization -- for example, the cost of generating and maintaining a new Allowance Parts List (APL) and establishing each new stock number. To take full advantage of standardization, it is necessary to understand the impact that the use of nonstandard components/equipments (C/Es) will have on the life-cycle cost of HM&E equipments.

1.3 TECHNICAL APPROACH

This study was conducted as follows:

- A life-cycle-cost (LCC) model was developed to identify the differences in the costs incurred when a nonstandard rather than a standard C/E is procured, entered into the Navy inventory, and supported throughout its inventory life.

- A standardization task work flow was developed to identify all of the efforts required as a result of imposing a standardization program on a shipbuilder -- efforts necessary for general support of the standardization program and those required to introduce a specific standard or nonstandard C/E into the Navy inventory.
- Data were collected and cost-estimating relationships were developed to convert task efforts into costs related to the C/E characteristics for application in the LCC model. C/E complexity was used to guide the evaluation of a wide range of C/Es.
- The life-cycle costs of typical C/Es of varying complexity were calculated by using the LCC model. These costs were then analyzed to identify the factors that have a significant impact on the cost difference between standard and nonstandard C/Es.

1.4 REPORT ORGANIZATION

The remaining chapters of this report describe the analyses performed to evaluate the costs related to standardization. Chapter Two identifies the organizations involved in the Navy standardization program. The development of the standardization life-cycle-cost model and necessary cost-estimating relationships is described in Chapter Three. Component/equipment complexity categories and the cost model input data are developed in Chapter Four. Chapter Five presents the life-cycle-cost calculations for the standard and nonstandard C/Es and a sensitivity analysis of the effects of varying cost-element inputs on overall life-cycle cost. Conclusions and recommendations are presented in Chapter Six.

CHAPTER TWO

NAVY STANDARDIZATION PROGRAM

2.1 BACKGROUND

The Navy Standardization program was established to curb the proliferation of components/equipments being introduced into the Fleet. Components/equipments (C/Es) are defined as repairable items that require repair part support when introduced into Naval operating forces, afloat or ashore. A standard C/E is defined as a one now in Navy use and supported by the logistics system. Several logistics studies have reported the existence of many nonstandard and low-population equipments requiring a large variety of repair parts that greatly increased the logistics inventory requirement. Nonstandardization has also contributed directly to the proliferation of allowance parts lists, technical manuals, configuration management, training, and other logistics requirements.

The Navy standardization policy is set forth as follows in NAVMATINST 4120.97A, 17 February 1971:

"a. Standardize designs -- with inter- and intra-system standardization of C/E and parts.

b. Reuse (in new design) existing, suitable C/E already supported in depth by the military system.

c. Preclude use of limited application and poor performance C/E.

d. Exercise configuration control to maintain standardization.

e. Use procurement techniques to restrain proliferation.

f. Effect item entry control in design selection and provisioning phases of material acquisition."

2.2 PROGRAM ORGANIZATION

Management of the Navy standardization program involves many commands and civilian contractors. This chapter identifies the organizations involved and their responsibilities associated with the overall standardization program, including the selection and support of components and equipments. The standardization relationship of each organization to the others is also addressed (see Figure 2-1).

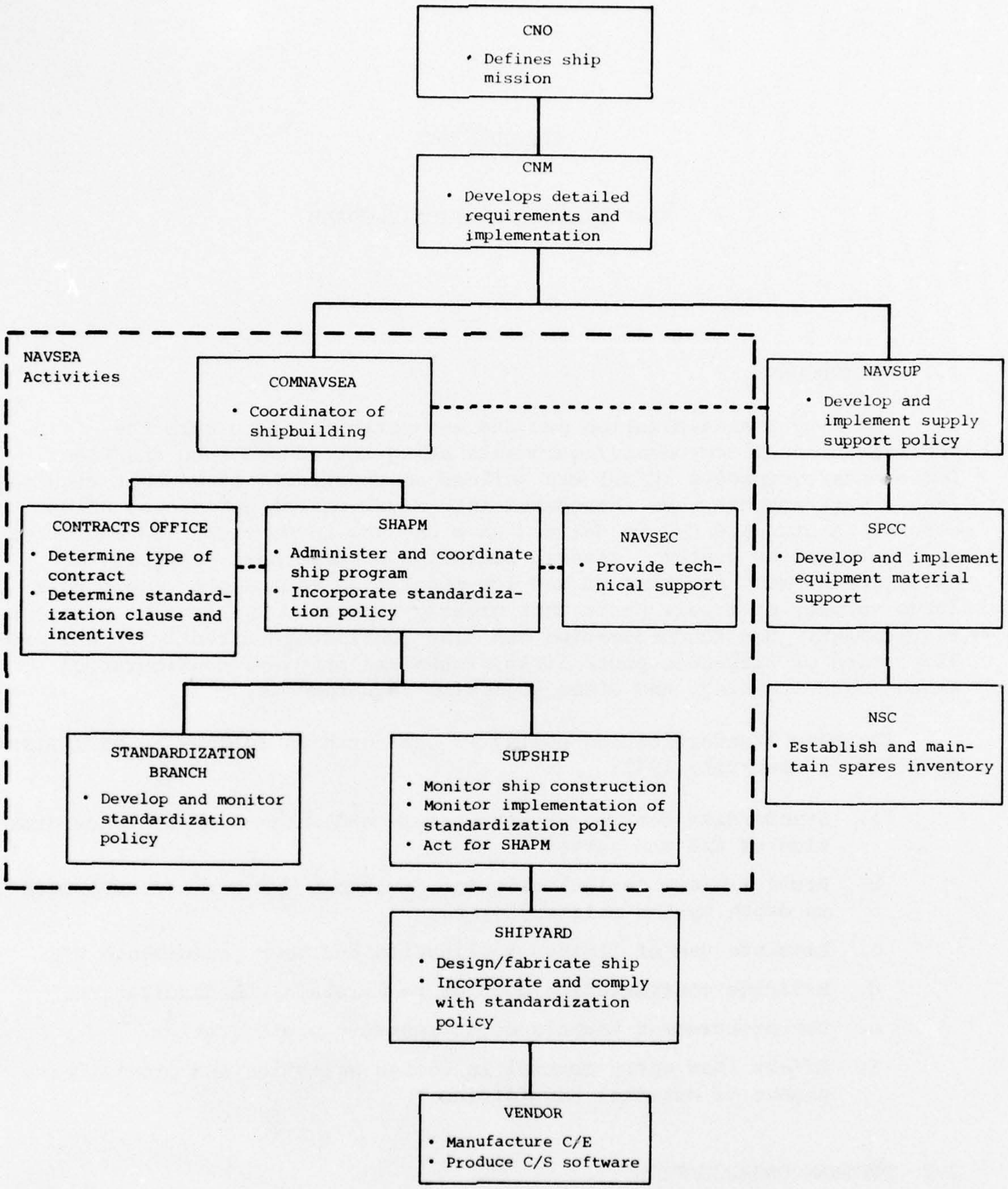

Chart shows functional relationships and does not reflect chain of command.

Figure 2-1. STANDARDIZATION RELATIONSHIPS

2.2.1 Chief of Naval Material

Under the immediate supervision of the Chief of Naval Operations (CNO), the Chief of Naval Material (CNM) is responsible for formulating and implementing Navy policies and procedures for the procurement and production of material required by the operating forces, and for coordinating and directing the efforts of the Navy commands and offices. The CNM provides policy direction to the Navy commands as to the objectives and requirements of the standardization program.

2.2.2 Ships Acquisition Project Manager

The Ships Acquisition Project Manager (SHAPM) is assigned the responsibility and delegated the authority for centralized management of the ship acquisition program, including all technical and business aspects. He is further responsible for coordinating ship material and technical support functions assigned to and discharged by other Systems Command and Project Managers to achieve maximum standardization among ships and equipments consistent with the NAVSEA standardization policy. To this end, he is responsible for incorporating the standardization policy, procedures, and guidance in acquisition contracts under his cognizance. He is required to monitor the shipyard standardization process developed in accordance with the individual ship construction contracts.

The SHAPM reports to the Commander, Naval Sea Systems Command (COMNAVSEA). The Commander is designated the head of a procuring activity, with attendant authority to enter into and administer material contracts, and he acts as Coordinator of Shipbuilding for the Navy. In these capacities, he reports to the Chief of Naval Material (CNM).

2.2.3 Naval Ship Engineering Center

The Naval Ship Engineering Center (NAVSEC) is responsible for preparing the ship specifications and contract drawings necessary for the acquisition of a ship. Standardization requirements to be invoked in the shipbuilding contract are incorporated into these specifications. NAVSEC is responsible to the SHAPM for providing any technical analyses required to evaluate C/E capabilities in meeting the ship specification requirements. This assistance may be provided directly to the Supervisor of Shipbuilding at a shipyard by direction of the SHAPM.

2.2.4 Standardization Branch

The Standardization Branch of NAVSEA is responsible for developing and monitoring the application of the NAVSEA standardization policy, general procedures, and guidance for the ship standardization programs. This responsibility includes providing technical support to the Naval Material Command in the development and implementation of NAVMAT policies and general procedures for standardization. The Standardization Branch acts

as the primary NAVSEA point of contact for coordinating ship standardization matters, including the coordination and establishment of the NAVSEA position on and implementation of policies and procedures proposed by higher authority.

The Branch provides guidance to the SHAPM and the Supervisor of Shipbuilding in the development of contract provisions necessary to meet the standardization requirements. This effort ranges from formulation of the contract clause that invokes standardization to coordination of the listings that classify equipments as standard components and equipments.

2.2.5 Shipbuilder

The shipbuilder is the focal point of the standardization issue. He is responsible for converting the ship design package into components and equipments for installation in the ship under construction. In discharging this responsibility, he will also realize his corporate goal of maximizing the profit obtainable under the contract terms.

The shipbuilder is responsible for determining the specific C/Es to be procured and installed. In addition, he is the contracting agent for the C/Es and must select the C/E vendor. When the C/E vendor is under contract, the shipbuilder must monitor, review, and evaluate the vendor's performance. The shipbuilder cooperates with the Supervisor of Shipbuilding in the review of required documentation and C/E analyses by the Navy. He coordinates with the Ships Parts Control Center in determining and submitting required provisioning technical documentation. Finally, he is responsible to the SHAPM that has cognizance of the contract for the overall ship construction.

2.2.6 Supervisor of Shipbuilding

The Supervisor of Shipbuilding represents the SHAPM in official transactions with the shipbuilder. He is responsible for monitoring the shipyard progress toward achieving the standardization goals and requirements set forth in the shipbuilding contract. In addition, he reviews and grants local approval of provisioning technical documentation, and he reviews and approves any testing performed on systems or C/Es when required by the contract or when an item has not previously been approved by the military.

2.2.7 Vendor

The vendor is responsible for manufacturing the C/Es procured by the shipbuilder for ship installation. Together with the hardware, the vendor must provide special tools as required for installation, check-out, and repair. He conducts maintenance engineering analyses, design reviews, and tests on the C/E. He is responsible for preparation of drawings, provisioning technical documentation, technical manuals or data sheets, test plans and reports, and training documentation as required.

The vendor reports to the shipbuilder for the definition of contract requirements. His association with the Ships Parts Control Center occurs during preparation of the required provisioning technical documentation for the C/Es. He works with the Navy Supply Center providing hardware (C/E) to maintain the required Navy inventory.

2.2.8 Ships Parts Control Center

The Ships Parts Control Center (SPCC) is responsible for processing the provisioning technical documentation for C/Es. It provides the mechanism by which the allowance parts lists (APL) reflecting the C/Es are brought into the supply system to determine and provide spare parts for the C/E when needed. SPCC is responsible to the Naval Supply Systems Command for implementing command policy in establishing spare support concepts. This responsibility includes analysis of the requirements for C/E spare parts types and quantities.

SPCC personnel work with SUPSHIP and the shipbuilder in the development and approval of provisioning technical documentation for the C/E. They obtain from the vendor the detailed technical information necessary for procurement of spares to support the C/E.

2.2.9 Navy Supply Center

The Navy Supply Center (NSC) is responsible for establishing and maintaining C/E spares inventories as determined by SPCC and for maintaining the records of inventory items, with their quantities. It provides the spares required to support ship C/E installations. The NSC coordinates with the organization requesting the spare.

2.3 STANDARDIZATION PROGRAM OPERATION

Standardization policies are formulated by the Naval Material Command. As discussed previously, NAVMATINST 4120.97A provides general guidance for implementing the standardization policy objectives. These objectives are translated into specific requirements for new ship construction contracts by the Ships Acquisition Project Manager, with assistance from the Standardization Branch within the Naval Sea Systems Command.

The Standardization Branch assists the SHAPM in preparing contracts by recommending standardization provisions for inclusion in the contract. The SHAPM prepares the contract and oversees the general performance of the contractor in satisfying the provisions of the contract. NAVSEC assists in the preparation of the technical portion of the contract by recommending design specifications. The shipbuilder utilizes the Standard Components List (SCL) and Master Integrated Allowance Parts List (MIAPL) developed by NAVSEC (Mechanicsburg Division) to identify recommended standard C/Es in accordance with the design specifications and standardization requirements invoked. He evaluates these C/Es and prepares alternate specifications as required; as necessary, additional data required to evaluate the recommended C/Es will be requested.

If a nonstandard C/E is selected, a study will be performed by the shipbuilder to evaluate and justify its use. This study will document the rationale for selecting a nonstandard C/E and estimate the effect of the shipbuilder's labor and materials. If a standardization exclusion applies, the study will be documented and maintained to avoid financial liability. Approval to use a nonstandard C/E when a standard is available will usually require the concurrence of the shipbuilder's Engineering, Purchasing, and Contracts Departments.

The shipbuilder then prepares procurement specifications for the selected C/Es, including standardization requirements and contract data requirement lists as specified by the contract. These specifications are sent to the vendors identified in the MIAPL. When the vendor's proposal is received,it is reviewed by the Shipyard Program Office and the Design, Integrated Logistic Support, and Procurement Departments to determine its compliance with the design and standardization requirements and the overall C/E cost. A vendor is then selected and a purchase order issued. The vendor prepares detailed plans in response to the purchase order. The shipbuilder reviews and revises the plans and releases them for manufacture, and the vendor initiates production of the required hardware and delivery to the shipbuilder for his acceptance.

Provisioning technical documentation (PTD) is required by the Navy to support determination of spare and repair parts required in the inventory to maintain the C/E. The PTD consists of drawings, lead APLs, proposed APLs, configuration identification indexes, and other component part data needed to fully describe the C/E to be provisioned. Requirements for the nonstandard and standard C/Es are the same; however, in the case of a standard C/E the documentation exists in the Navy system and is already approved. The vendors' actions are then structured toward a Certificate of Identicality to provide positive identification of the Component Item Description (CID) number representing standard components and equipments. For nonstandard C/Es, documentation must first be developed in accordance with military format requirements and approved by the Navy.

The Ships Parts Control Center (SPCC) personnel process the PTD and identify the repair parts requirements. The documentation is reviewed and screened to determine content,and a control number is assigned. Its adequacy is then evaluated and a determination is made as to the agency that will manage the repair parts identified in the APL. Additional item management coding actions are completed, and the range and depth of the recommended stock purchase are determined. Information required to adequately represent the provisioned item is cataloged, and a quality assurance review of all information is conducted. In the case of a standard C/E, not all of these actions are necessary. Efforts are limited to clerical screening, verification of component/equipment identicality, and a determination of increased depth of repair parts required. SPCC is also responsible for maintaining the records for all the new C/Es and associated National Stock Numbers (NSNs) -- a continuing management task that must be performed for the service life of the C/E.

Navy requirements call for a substantial amount of C/E documentation. The nonstandard C/E produced by a vendor must satisfy several Navy requirements before it is introduced into Navy service. The vendor initiates the documentation to support these requirements. The vendor's task performance is normally managed by the shipbuilder and monitored by the local SUPSHIP office and must meet rigid Navy specifications.

C/E documentation includes that required to describe the installation, operation, and maintenance of the C/E. It encompasses the results of analyses for determining design actions and maintenance philosophy. Drawings are utilized by the shipyard for C/E installation planning, interface, and check-out, and in support of system level testing. They are required by the Ships Parts Control Center (SPCC) to support part identification and competitive procurement.

SUPSHIP is responsible for review, approval, and acceptance of technical data from the shipbuilder. These data may be generated by the shipbuilder or by a vendor as part of a shipbuilder's C/E procurement. Technical manuals are required to operate and maintain the equipments. Specific requirements for manuals are dependent on the shipbuilder's requirement as driven by the overall shipbuilding contract.

The introduction of nonstandard C/Es may require the development of a new training program or the modification of an existing program. Course material and the assignment of instructors are also approved by the shipbuilder and local SUPSHIP offices. The training plan is then coordinated with the SHAPM.

The Navy Supply Centers store and maintain the end items, repairables, and consumables required for ship maintenance. Initial stockage levels are determined by the Inventory Control Point provisioning efforts. These initial estimates are then updated by actual usage data. The use of a nonstandard C/E requires the introduction of the new NSNs into the logistics support system data by adding NSN data to the records, opening new stock bins, and establishing new inventories. These inventories are then maintained in depots, tenders, and the ships using the new C/E.

2.4 STANDARDIZATION PROGRAM PROBLEMS

Problems encountered in applying standardization to a shipbuilding program include the formulation of the contract requirement to invoke standardization, the decision process for selecting the standard/nonstandard C/E to be used, and the evaluation of the level of standardization achieved.

In 1967, as a part of its effort to achieve equipment standardization in new ship construction, the Navy developed a general Equipment Standardization Incentive Clause for new construction contracts. The objective of the Equipment Standardization Incentive Clause is "...to increase maintainability of shipboard equipment and reduce cost of logistic support by

encouraging installation in the vessel of equipments identical to those already installed in U.S. Navy ships and for which Allowance Parts Lists (APL) have already been prepared or are pending..." The incentive clause provides for an increase in the contract price if at least a specified percentage of the contractor-furnished equipments in each of several selected categories are supported by existing or pending APLs. The incentive amount is determined by the lowest percent of APL-supported equipment attained in any of the categories included in the incentive clause; no incentive payment is made if any category falls below the specified percentage mark. The amount of the incentive increases only when the lowest percentage by category increases.

Another clause utilized by the Navy is the Penalty Clause, which has the same objective as the Incentive Clause but penalizes the shipbuilder a specific amount for each new National Stock Number (NSN) introduced into the supply system as a result of introducing nonstandard C/Es. The current penalty amount for each new NSN is $4,400.

The shipbuilder has a trade-off to make: his saving from using a nonstandard C/E as offset by a contract penalty, if any, or the incentive fee he stands to lose, if any, if he selects the nonsupported equipment. The shipbuilder's savings lie primarily in the difference between the acquisition prices of the supported and nonsupported equipments. In considering the acquisition price of a nonsupported equipment, the shipbuilder must take into account the cost of technical documentation and component qualification testing if required. Even with these additional costs, the shipbuilder might find that the acquisition price of a non-APL-supported item is appreciably lower than that of an equivalent item currently supported. It is possible, in fact, that the shipbuilder will save an amount greater than the entire incentive or penalty by selecting one non-APL-supported equipment -- particularly if the contract is for a large number of ships.

The problem then, is to develop an adequate standardization clause to ensure that standardization goals are achieved, recognizing the requirements of the standardization program and the profit motivation of the shipbuilder.

The decision process for selecting the standard or nonstandard C/E takes place almost entirely at the shipbuilder's level. He must be responsive to both the Navy requirements and C/E vendor constraints. The Navy imposes standardization goals, equipment specifications, and program deadlines. The shipbuilder must then identify the vendor and component that will satisfactorily meet these needs. If his contract includes cost or incentive clauses, he must also determine the C/E that offers him the greatest profit potential. This process tends to place primary emphasis on selecting C/Es with the lowest acquisition cost.

The method of evaluating the level of standardization achieved during the shipbuilding program must be oriented to support the original standardization requirement. Calculation of existing NSNs versus newly

introduced NSNs can provide a false expression of standardization in terms of life-cycle cost. Calculating the percentage of standard C/Es can also be misleading because the cost to the Navy can vary greatly among different C/Es. A more complex C/E could require considerably more effort and cost to introduce and support than a less complex C/E. Consequently, the degree of standardization, in terms of percentage, could be very high but include a large quantity of simple C/Es. If the complex C/Es are not included, the full value of standardization may not be realized.

This study was performed to assist in the decision process for selecting a standard or nonstandard component/equipment. The application of the life-cycle-cost model for standardization, as developed in the study, provides a method for determining the quantitative cost difference during the life cycle of a standard versus a nonstandard component/equipment.

CHAPTER THREE

LIFE-CYCLE-COST MODEL FOR STANDARDIZATION

The Naval Engineering Support Activity recently developed a life-cycle-cost guide* for the Naval Material Command; it includes a model for identifying elements that influence life-cycle costs in three phases of an equipment's life cycle -- Research and Development, Investment, and Operation and Support. The guide also presents a life-cycle-cost breakdown structure, which is reproduced in Table 3-1.

The life-cycle-cost guide was used in this study to develop a life-cycle-cost model for standardization. Since standardization is concerned only with the difference between the life-cycle costs of standard and nonstandard C/Es, several cost elements were omitted and the cost model simplified accordingly. The following criteria were used in developing the life-cycle-cost model for standardization:

- The model is applicable to C/Es that have the same capabilities and perform the same functions.
- The model is not applicable when state-of-the-art improvements are involved.

3.1 LIFE-CYCLE-COST ELEMENTS

The life-cycle-cost elements presented in Table 3-1 were reviewed to identify and eliminate those which do not influence the cost of standardization. Elements identified as not relevant are discussed below.

3.1.1 Research and Development Cost Elements

Research and Development costs are incurred when a new C/E is being designed and developed. Since this phase occurs only when existing equipment is not suitable, there is no choice between standard and nonstandard equipments; therefore, all cost elements in the Research and Development Phase are omitted.

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*"Life Cycle Cost Guide for Equipment Analysis", the Naval Weapons Engineering Support Activity, Washington, D.C., January 1977.

Table 3-1. LIFE-CYCLE-COST BREAKDOWN STRUCTURE

Research and Development

- Validation
  - Contractor
  - Government
- Full-Scale Development
  - Contractor
    - Management
    - Engineering
    - Prototype Hardware
    - Software
    - Test and Evaluation
    - Documentation
    - Support and Test Equipment
  - Government - Program Management
    - Training
    - Test Site Activation
    - Test and Evaluation

Investment

- Government Program Management
- Prime Equipment Acquisition
  - Production Hardware
  - Production Support and Services
  - Production Test and Evaluation
  - Transportation
  - Installation and Check-Out
- Initial Support Acquisition
  - Support and Test Equipment Acquisition
  - Supply Support
    - Initial Spares
      - Prime Equipment
      - Support and Test Equipment
    - APL Entry Into the Supply System
    - NSN Entry Into the Supply System
- Facilities
  - Operational
  - Maintenance
- Documentation
  - Acquisition
  - Reproduction and Distribution
- Training
  - Operator
  - O/I-Level Maintenance
  - Depot-Level Maintenance
  - Instructor
  - Training Aids

Operation and Support

- Operation
  - Personnel
  - Facilities
  - Energy Consumption
  - Material Consumption
  - Software Maintenance
- Support
  - Corrective Maintenance
    - Labor
      - O/I Level (Remove and Replace)
      - O/I Level (Repair)
      - Depot Level (Repair)
    - Repair Material
    - Transportation and Packaging
      - Material Handling Labor
      - Packaging Material
      - Shipping
  - Preventive Maintenance
    - Labor
    - Material
  - Overhaul
    - Labor
    - Material
    - Tansportation
  - Support and Test Equipment Maintenance
  - Facilities
    - Shop Space
      - O/I Level
      - Depot Level
    - Inventory Storage
      - O/I Level
      - Depot Level
  - Documentation Maintenance
  - Supply Support
    - Replenishment Spares
    - Supply System Management
  - Training
    - Operator
    - O/I Level Maintenance
    - Depot Level Maintenance
- Termination

3.1.2 Investment Cost Elements

3.1.2.1 Prime Equipment Acquisition - Transportation

The transportation cost element is not dependent on whether the C/E is standard or nonstandard. It is dependent on the specific characteristics of the C/E (e.g., size, weight, material) and the distance between the vendor and the shipyard. It is not considered a cost-influencing element for the purpose of this study.

3.1.2.2 Prime Equipment Acquisition - Installation and Check-Out

Discussions with shipyard personnel indicated no appreciable effect on engineering time and cost as a result of installation and check-out of a nonstandard C/E versus a standard C/E. The differences that might result would be applicable to documentation requirements and quantity and type of spares. These are dependent on the nature of the C/E and not on the difference between standard and nonstandard. This element is not included as an influencing cost.

3.1.2.3 Initial Support Acquisition - Facilities

Facility costs are required whether the C/E is standard or nonstandard. Additional requirements, if any, are not considered to be the result of utilizing a nonstandard C/E, and this element is not included as an influencing cost.

3.1.3 Operation and Support

3.1.3.1 Operation

All cost elements associated with operation are considered independent of whether the C/E is standard or nonstandard. Unless the nonstandard C/E under consideration is significantly more complex in operation and of a different state of the art than its standard counterpart, this category is not considered as an element influencing cost.

3.1.3.2 Support - Facilities (Shop Space)

On the assumption that standard and nonstandard C/Es of similar complexity and capability would be evaluated, the facilities (shop space) were determined as not influencing the life-cycle-cost difference.

3.1.3.3 Termination

Termination cost is equivalent to the salvage market value less the disposal cost. This element is independent of whether the C/E is standard or nonstandard and is therefore omitted.

3.2 LIFE-CYCLE-COST MODEL ELEMENTS

Screening of the cost elements to identify those influencing the cost of standardization produced the cost elements listed in Table 3-2. These cost elements are used to develop the life-cycle-cost equation for standardization. The life-cycle cost is the sum of the cost elements of the two major cost groups identified as investment and support.

Table 3-2. LIFE-CYCLE-COST BREAKDOWN STRUCTURE (REDUCED)

Investment	Support
Government Program Management Prime Equipment Acquisition Production Hardware Production Support and Services Production Test and Evaluation Initial Support Acquisition Support and Test Equipment Acquisition Supply Support • Initial Spares •• Prime Equipment •• Support and Test Equipment • APL Entry Into the Supply System • NSN Entry Into the Supply System Documentation • Acquisition • Reproduction and Distribution Training • Operator • O/I-Level Maintenance • Depot-Level Maintenance • Instructor • Training Aids	Corrective Maintenance • Labor •• O/I Level (Remove and Replace) •• O/I Level (Repair) •• Depot Level (Repair) • Repair Material • Transportation and Packaging •• Material Handling Labor •• Packaging Material •• Shipping Preventive Maintenance • Labor • Material Overhaul • Labor • Material • Transportation Support and Test Equipment Maintenance Facilities • Inventory Storage •• O/I Level •• Depot Level Document Maintenance Supply Support • Replenishment Spares • Supply System Management Training • Operator • O/I-Level Maintenance • Depot-Level Maintenance

3.3 STANDARDIZATION WORK FLOW

During the course of the study, numerous personnel from the Naval Sea Systems Command, Naval Supply Systems Command, and Naval Facilities Engineering Command were interviewed. Visits were made to the Navy Ships Parts Control Center, Mechanicsburg, Pennsylvania, and Navy Supervisor of Shipbuilding Offices at Newport News, Virginia; Pascagoula, Mississippi; and Seattle, Washington. Visits were also made to Lockheed Shipbuilding, Seattle, Washington; Newport News Shipbuilding and Drydock Co., Newport News, Virginia; and Ingalls and Todd Shipbuilding, Seattle, Washington. These interviews were conducted to identify work tasks that contribute to life-cycle cost when a nonstandard component is being introduced in lieu of a standard component.

The tasks and associated documentation requirements are presented in Figure 3-1, which depicts the work flow within the various Navy organizations, the shipbuilder, and the vendor. The actions which normally occur, those which are unique to a standardization program, and those which differ for standard and nonstandard items are shown.

The tasks from Figure 3-1 were next grouped into the cost-element categories presented in Table 3-3. The tasks are also categorized as those which apply to all C/Es, those which are standardization program tasks, and those which are unique to nonstandard or standard C/Es.

3.4 LIFE-CYCLE-COST MODEL FOR STANDARDIZATION

The cost elements of Table 3-2 and the tasks presented in Figure 3-1 and tabulated in Table 3-3 were used to modify the life-cycle-cost model originally developed by the Naval Weapons Engineering Support Activity. The result is the life-cycle-cost model for standardization presented in Table 3-4. This model is represented by a series of equations for the various cost elements, the sum of which is the total life-cycle-cost equation. Also presented are the cost factor descriptors and dimensions. The primary and intermediate model inputs (cost factors) are identified in the right-hand column; the model outputs are the individual cost elements shown in the left-hand column.

The model developed is a complete life-cycle-cost model within the framework of the study assumptions; it was developed for use at the component/equipment level. One of its limitations is that it does not include the reduction in costs associated with a smaller number of spares required in the Navy Supply System because standardization is invoked. The model, or series of equations, lends itself to simplification in application depending on the level of detail required, particularly when it is computerized.

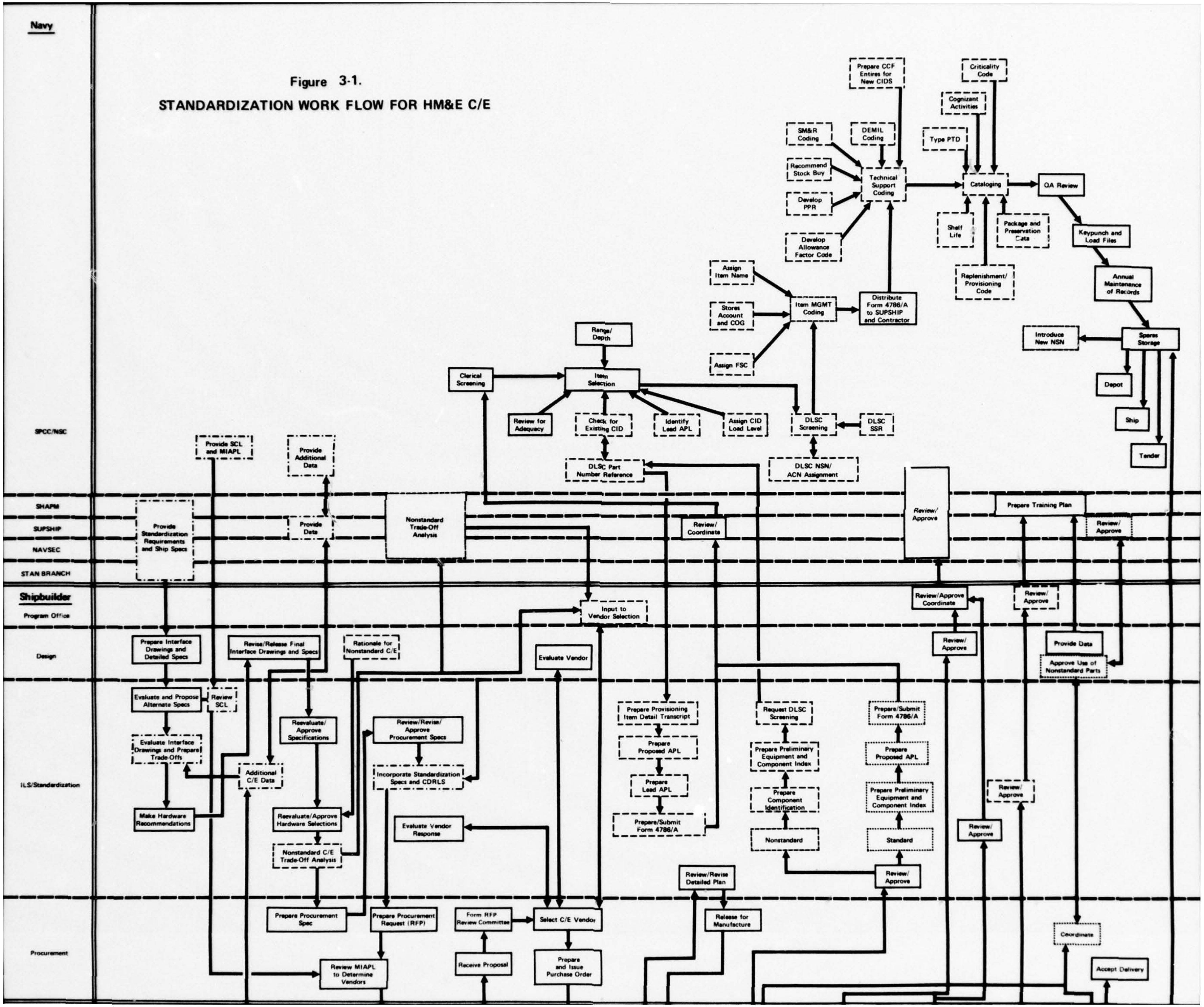
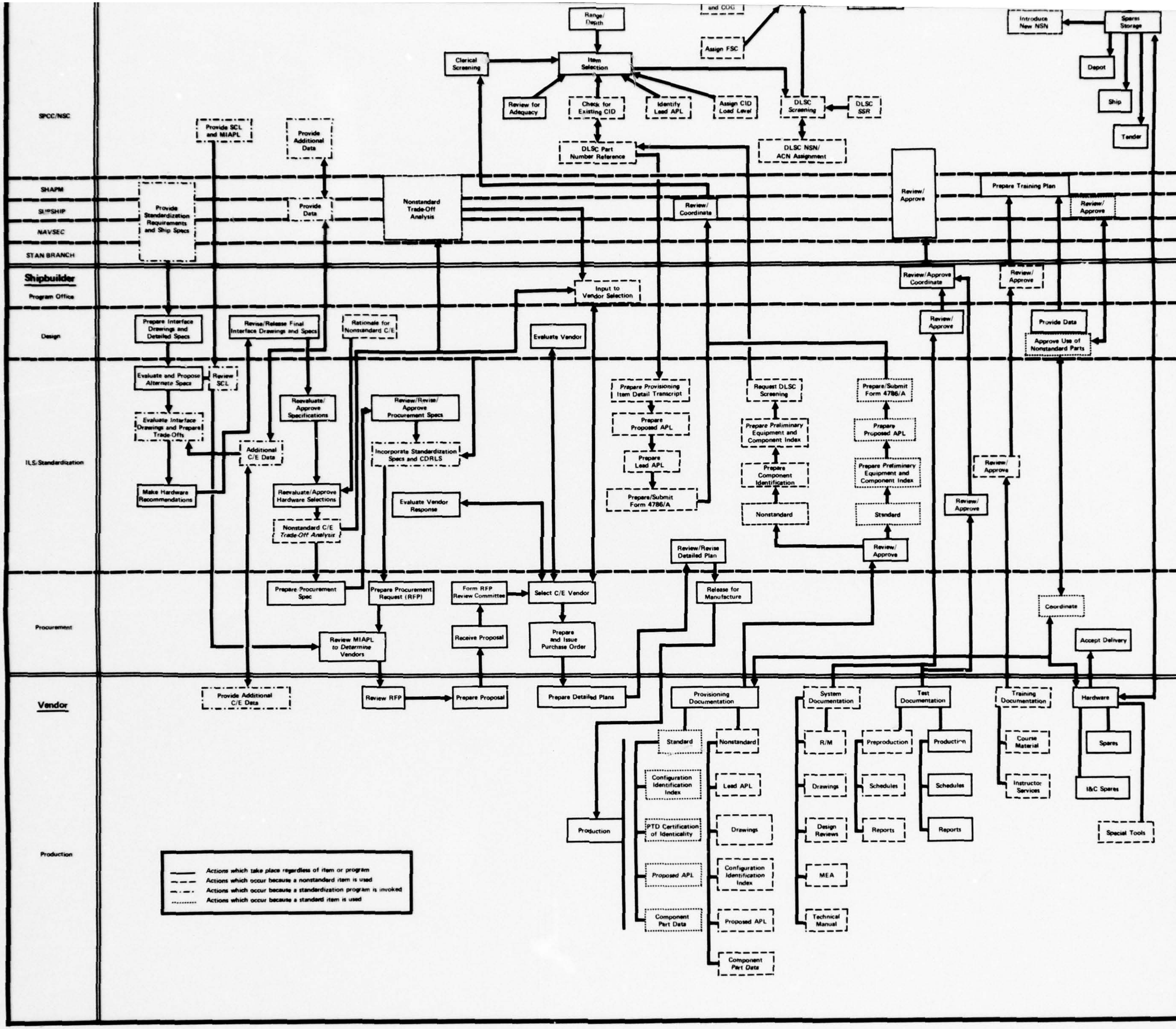


Figure 3-1.
STANDARDIZATION WORK FLOW FOR HM&E C/E



SPCC/NSC
SHAPM
SUPSHIP
NAVSEC
STAN BRANCH
Shipbuilder
Program Office
Design
ILS/Standardization
Procurement
Vendor
Production
and COG
Range/Depth
Item Selection
Clerical Screening
Review for Adequacy
Check for Existing CID
Identify Lead APL
Assign CID Load Level
Assign FSC
DLSC Screening
DLSC SSR
DLSC Part Number Reference
DLSC NSN/ ACN Assignment
Introduce New NSN
Spares Storage
Depot
Ship
Tender
Provide SCL and MIAPL
Provide Additional Data
Provide Standardization Requirements and Ship Specs
Provide Data
Nonstandard Trade-Off Analysis
Review/ Coordinate
Review/ Approve
Prepare Training Plan
Review/ Approve
Input to Vendor Selection
Review/Approve Coordinate
Review/ Approve
Prepare Interface Drawings and Detailed Specs
Revise/Release Final Interface Drawings and Specs
Rationale for Nonstandard C/E
Evaluate Vendor
Provide Data
Approve Use of Nonstandard Parts
Review/ Approve
Evaluate and Propose Alternate Specs
Review SCL
Reevaluate/ Approve Specifications
Review/Revise/ Approve Procurement Specs
Evaluate Interface Drawings and Prepare Trade-Offs
Additional C/E Data
Incorporate Standardization Specs and CDRLS
Make Hardware Recommendations
Reevaluate/Approve Hardware Selections
Nonstandard C/E Trade-Off Analysis
Evaluate Vendor Response
Prepare Provisioning Item Detail Transcript
Prepare Proposed APL
Prepare Lead APL
Prepare/Submit Form 4786/A
Request DLSC Screening
Prepare Preliminary Equipment and Component Index
Prepare Component Identification
Nonstandard
Prepare/Submit Form 4786/A
Prepare Proposed APL
Prepare Preliminary Equipment and Component Index
Standard
Review/ Approve
Review/ Approve
Review/ Approve
Review/Revise Detailed Plan
Prepare Procurement Spec
Prepare Procurement Request (RFP)
Form RFP Review Committee
Select C/E Vendor
Release for Manufacture
Coordinate
Receive Proposal
Prepare and Issue Purchase Order
Review MIAPL to Determine Vendors
Accept Delivery
Provide Additional C/E Data
Review RFP
Prepare Proposal
Prepare Detailed Plans
Provisioning Documentation
System Documentation
Test Documentation
Training Documentation
Hardware
Standard
Configuration Identification Index
PTD Certification of Identicality
Proposed APL
Component Part Data
Nonstandard
Lead APL
Drawings
Configuration Identification Index
Proposed APL
Component Part Data
R/M
Drawings
Design Reviews
MEA
Technical Manual
Preproduction
Schedules
Reports
Production
Schedules
Reports
Course Material
Instructor Services
Spares
I&C Spares
Special Tools
Production
Actions which take place regardless of item or program
Actions which occur because a nonstandard item is used
Actions which occur because a standardization program is invoked
Actions which occur because a standard item is used

2

Table 3-3. DISCRETE TASK EFFORTS

Cost Elements	Common Task for All C/E	Program Task	Nonstandard C/E Tasks	Standard C/E Tasks
INVESTMENT				
<u>Government Program Management</u>				
• Standardization branch assists SHAPM in preparing contract		X		
• SHAPM prepares contract standardization requirements		X		
• NAVSEC develops standardization design specifications		X		
• NAVSECMECHDIV provides SCL & MIAPL		X		
• SUPSHIP interfaces with shipbuilder		X		
• SPCC provides additional C/E data		X		
• SHAPM evaluates C/E selection			X	
• NAVSEC evaluates C/E selection			X	
• SUPSHIP evaluates C/E selection			X	
• SUPSHIP reviews all documentation			X	X
• SHAPM reviews system, test & training documentation			X	X
• NAVSEC reviews system & test documentation			X	X
• SUPSHIP approves use of nonstandard parts				X
PRIME EQUIPMENT ACQUISITION				
<u>Production Hardware</u>				
• Shipyard reviews ship specifications and prepares the interface drawings and equipment specifications	X			
• Shipyard reviews SCL		X		
• Shipyard evaluates interface drawings and prepares trade-offs for standard C/E		X		
• Shipyard makes hardware selection	X			
• Shipyard revises and approves drawings and specifications	X			
• Shipyard evaluates and justifies use of nonstandard C/E			X	
• Shipyard approves use of nonstandard parts				X
• Shipyard prepares procurement specifications	X			
• Shipyard incorporates standardization specifications		X		
• Shipyard prepares and issues RFP	X			
• Shipyard identifies potential vendors	X			
• Vendor prepares proposal	X			
• Shipyard evaluates RFP responses	X			
• Shipyard selects vendor	X			
• Shipyard prepares and issues purchase order	X			
• Vendor prepares detailed plan	X			
• Shipbuilder approves plan	X			
• Vendor produces C/E			X	X
• Shipyard accepts hardware	X			
<u>Production Test & Evaluation</u>				
• Vendor produces test documentation			X	X
• Shipbuilder reviews test documentation			X	X
INITIAL SUPPORT ACQUISITION				
<u>Support & Test Equipment Acquisition</u>				
• Vendor produces special tools, jigs, etc.			X	X
<u>Supply Support</u>				
• Vendor produces spares			X	X
• Vendor produces provisioning technical documentation			X	X
• Shipbuilder reviews and completes PTD			X	X
• SPCC clerical screening			X	X
• SPCC item selection			X	X
• SPCC DLSC screening			X	
• SPCC item management coding			X	
• SPCC distributes Form 4786	X			
• SPCC technical support coding			X	
• SPCC cataloging			X	
• SPCC quality assurance review			X	X
• SPCC keypunch and load files			X	X
• SPCC annual maintenance of records			X	X
<u>Documentation</u>				
• Vendor produces system documentation			X	X
• Shipbuilder reviews/completes system documentation			X	X
<u>Training</u>				
• Vendor produces training documentation			X	
• Shipbuilder reviews/completes training documentation			X	
SUPPORT				
<u>Supply Support</u>				
• NSC introduces NSNs			X	
• Depot stocks C/E			X	X
• Tender stocks C/E			X	X
• Ship stocks C/E			X	X

Table 3-4. STANDARDIZATION PROGRAM LIFE-CYCLE-COST MODEL

Cost Element	Equation	Cost Factor Description	Model Input (P) Primary (I) Intermediate
INVESTMENT			
Government Program Management	$\sum_{I=1}^{Y} PMGG(I) + \sum_{I=1}^{Y} PMGH(I) + \sum_{I=1}^{Y} PMGI(I) +$	PMGG(I) = SHAPM evaluation of C/E selection ($/yr)	I
		PMGH(I) = NAVSEC evaluation of C/E selection ($/yr)	I
	$\sum_{I=1}^{Y} PMGJ(I) + \sum_{I=1}^{Y} PMGK(I) +$	PMGI(I) = SUPSHIP evaluation of C/E selection ($/yr)	I
		PMGJ(I) = SUPSHIP documentation review ($/yr)	I
		PMGK(I) = SHAPM review of system, test, and training documentation ($/yr)	I
	$\sum_{I=1}^{Y} PMGL(I) + \sum_{I=1}^{Y} PMGM(I)$	PMGL(I) = NAVSEC review of system and test documentation ($/yr)	I
		PMGM(I) = SUPSHIP approval of nonstandard item ($/yr)	I
	where: I = Designator for a specific project year Y = Number of years covered by the life-cycle-cost analysis		
	PMGG(I) = LBB × HRG	LBB = SHAPM labor rate ($/hr)	P
	PMGH(I) = LBC × HRH	LBC = NAVSEC labor rate ($/hr)	P
	PMGI(I) = LBE × HRI	LBE = SUPSHIP labor rate ($/hr)	P
	PMGJ(I) = LBE × HRJ	HRG = Number of hours (hr)	P
	PMGK(I) = LBB × HRK	HRH = Number of hours (hr)	P
	PMGL(I) = HRN × NAP	HRI = Number of hours (hr)	P
	PMGM(I) = LBE × HRM	HRJ = Number of hours (hr)	P
		HRK = Number of hours (hr)	P
		HRM = Number of hours (hr)	P
		HRN = Review cost per APL ($/APL)	P
		NAP = Number of APLs (APLs)	P
Prime Equipment Acquisition			
Production Hardware	$\sum_{I=1}^{Y} NN(I) \times CU + \sum_{I=1}^{Y} PHB(I) +$	$\sum_{I=1}^{Y}$ NN(I) * CU = Prime equipment procurement cost ($/yr)	I
	$\sum_{I=1}^{Y} PHC(I) + \sum_{I=1}^{Y} PHF(I) + \sum_{I=1}^{Y} PHH(I) +$	$\sum_{I=1}^{Y}$ PHB(I) = Shipyard cost to review SCL ($/yr)	I
	$\sum_{I+1}^{Y} PHR(I)$	$\sum_{I=1}^{Y}$ PHC(I) = Shipyard cost for trade-off evaluation ($/yr)	I
		$\sum_{I=1}^{Y}$ PHF(I) = Shipyard cost for evaluation of use of nonstandard C/E ($/yr)	I
		$\sum_{I=1}^{Y}$ PHH(I) = Shipyard cost to incorporate standardization specifications ($/yr)	I
		$\sum_{I=1}^{Y}$ PHR(I) = Shipyard cost to approve use of nonstandard item ($/yr)	I
		NN(I) = Prime equipment annual acceptance schedule (equip/year)	P
		CU = Prime equipment procurement price ($/equip)	P
	PHB(I) = AHA × NHB	AHA = Shipyard labor rate ($/hr)	P
	PHC(I) = AHA × NHC	NHB = Number of hours (hr) to review SCL	P
	PHF(I) = AHA × NHF	NHL = Number of hours (hr) for trade-off evaluation	P
	PHH(I) = AHA × NHH		
	PHR(I) = PHS × PHT	NHF = Number of hours (hr) for nonstandard C/E evaluation	P
		NHH = Number of hours (hr) to incorporate standardization specifications	P
		PHS = Cost per nonstandard item ($/item)	P
		PHT = Number of nonstandard items (items)	P

(continued)

Table 3-4. (continued)

Cost Element	Equation	Cost Factor Description	Model Input (P) Primary (I) Intermediate
Prime Equipment Acquisition (continued)			
Production Support & Services	$\sum_{I=1}^{Y} PSS(I)$	PSS(I) = Production support and services cost (\$/yr)	P
Production Test & Evaluation	$\sum_{I=1}^{Y} PTE(I) = \sum_{I=1}^{Y} EPT(I) + \sum_{I=1}^{Y} TD(I) +$	$\sum_{I=1}^{Y} EPT(I)$ = Equipment production test costs (\$/yr)	I
	$\sum_{I=1}^{Y} RTD(I)$	$\sum_{I=1}^{Y} TD(I)$ = Test documentation cost (\$/yr)	I
		$\sum_{I=1}^{Y} RTD(I)$ = Shipyard cost to review test documentation (\$/yr)	I
	$EPT(I) = PTC(I) \times PET(I)$	PTC(I) = Cost to test each item (\$/item)	P
	$TD(I) = PPC(I) \times TDP(I)$	PET(I) = Number of items tested (items/yr)	P
	$RTD(I) = AHA \times HRT(I)$	PPC(I) = Cost per page of test documentation (\$/page)	P
		TDP = Number of pages of test documentation (pages/year)	P
		AHA = Shipyard labor rate (\$/hr)	P
		HRT(I) = Number of hours to review test documentation (hr/year)	P
Initial Support Acquisition			
• Support & Test Equipment Acquisition	$\sum_{I=1}^{Y} STE(I)$	STE(I) = Support & test equipment acquisition costs (\$/year)	P
-Initial Spares			
Prime Equipment	$\sum_{I=1}^{Y} NN(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times$	NN(I) = Prime equipment annual acceptance schedule (equip/year)	P
	$CST(K) \times \left[DSC(K) \times (FPST + FILS) + [1-DSC(K)] \times [RSS(K) \times FIRT + [1-RSS(K)] \times FDRT]\right] / [R(K) \times FR(I) \times 365]$	OT = Prime equipment annual operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (quantity/item)	P
		CST(K) = Unit cost of the K^{th} item (\$/item)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
	K = Designator for a specific spare/repair item in an equipment	FPST = Procurement lead & safety stockage time for spares (days)	P
	NK = The number of spare/repair items in an equipment	FILS = Required stockage time at O/I level for spares (days)	P
		RSS(K) = Repair level ratio (ratio)	P
		FIRT = Required stockage time for O/I repairable items (days)	P
		FDRT = Required stockage time for depot repairable items (days)	P
		R(K) = Mean time between failures for K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
Support & Test Equipment	$\sum_{I=1}^{Y} STE(I) \times STEM$	STE(I) = Support & test equipment acquisition cost (\$/yr)	P
		STEM = Material support rate; percent of S&TE cost (ratio)	P
-APL Entry into the Supply System	$\sum_{I=1}^{Y} NAPL \times CPL + \sum_{I=1}^{Y} PAPL \times (NAP + NAPS)$	PAPL = Cost to prepare APL (\$/APL)	P
		CPL = Cost to process APL line item (\$/item)	P
		NAPL = Number of APL line items (line item)	[illegible]
		NAP = Number of APLs for prime equipment (APL)	[illegible]
-NSN Entry into the Supply System	$\sum_{I=1}^{Y} (NSNP + NSNS) \times CNP$	NAPS = Number of APLs for support and test equipment (APL)	P
		NSNP = Number of new NSNs of primary equipment (NSN)	I
		NSNS = Number of new NSNs of support & test equipment (NSN)	I
		CNP = Cost to process new NSN (\$/NSN)	P

(continued)

Table 3-4. (continued)

Cost Element	Equation	Cost Factor Description	Model Input (P) Primary (I) Intermediate
Initial Support Acquisition (continued)			
• Documentation			
- Acquisition	$\sum_{I=1}^{Y} AD(I) = \sum_{I=1}^{Y} CACP \times ACP + \sum_{I=1}^{Y} CHCP \times HCP + \sum_{I=1}^{Y} CACD \times ACDP + \sum_{I=1}^{Y} CHCD \times HCDP$	CACP = Cost per page for average complexity technical manual ($/page)	P
		ACP = Number of pages of average complexity technical manual (pages)	P
		CHCP = Cost per page for high complexity technical manual ($/page)	P
		HCP = Number of pages of high complexity technical manual (pages)	P
		CACD = Cost for average complexity drawings ($/drawing)	P
		ACDP = Number of average complexity drawings (drawings)	P
		CHCD = Cost for high complexity drawings ($/drawing)	P
		HCDP = Number of high complexity drawings (drawings)	P
- Reproduction & Distribution	$\sum_{I=1}^{Y} NC(I) \times NP \times CP$	NC(I) = Number of copies (copies/yr)	P
		NP = Number of pages in a set of technical data (pages)	P
		CP = Reproduction and distribution costs ($/page/copy)	P
• Training			
- Operator	$\sum_{I=1}^{Y} PTO(I) \times CTO$	PTO(I) = Number of students (students/yr)	P
		CTO = Operating personnel training cost ($/student)	P
- O/I Level Maintenance	$\sum_{I=1}^{Y} PTM(I) \times CTM$	PTM(I) = Number of students (students/yr)	P
		CTM = O/I maintenance personnel training costs ($/student)	P
- Depot Level Maintenance	$\sum_{I=1}^{Y} PTP(I) \times CTP$	PTP(I) = Number of students (students/yr)	P
		CTP = Depot maintenance personnel training costs ($/student)	P
- Instructor	$\sum_{I=1}^{Y} PTI(I) \times CTI$	PTI(I) = Number of students (students/yr)	P
		CTI = Instructor training costs ($/students)	P
- Training Aids	$\sum_{I=1}^{Y} ATU(I)$	ATU(I) = Acquisition and installation costs of training aids	P
SUPPORT			
Corrective Maintenance			
• Labor			
- O/I Level (Remove & Replace)	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times LSO(K) \times RSL/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (quantity/item)	P
		LSO(K) = O/I maintenance time to remove, replace K^{th} item (hrs/item)	P
		RSL = O/I maintenance personnel pay rate ($/hr)	P
		R(K) = Mean time between failures for K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P

(continued)

Table 3-4. (continued)			
Cost Element	**Equation**	**Cost Factor Description**	**Model Input (P) Primary (I) Intermediate**
Corrective Maintenance (continued)			
• Labor			
- O/I Level (Repair)	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times$ $LSI(K) \times RSL \times RSS(K) \times [1-DSC(K)]/$ $[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (quantity/item)	P
		LSI(K) = O/I maintenance time to repair the K^{th} item (hrs/item)	P
		RSL = O/I maintenance personnel pay rate ($/hr)	P
		RSS(K) = Repair level ratio (ratio)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
- Depot Level (Repair)	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times$ $LSD(K) \times RSD \times [1-RSS(K)]$ $[1-DSC(K)]/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		LSD(K) = Depot maintenance time to repair K^{th} item (hrs/item)	P
		RSD = Depot maintenance personnel pay rate ($/hr)	P
		RSS(K) = Repair level ratio (ratio)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
• Repair Material	$\sum_{I=1}^{Y} N(I) \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times$ $CST(K) \times FM \times [1-DSC(K)]/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		CST(K) = Unit cost of K^{th} item ($/item)	P
		FM = Repair material rate percent of item cost (ratio)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
• Transportation and Packaging			
- Material Handling Labor	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times$ $2 \times W(K) \times RPL \times [1-RSS(K)] \times$ $[1-DSC(K)]/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		W(K) = Weight of K^{th} item (lb)	P
		RPL = Packaging labor cost ($/lb)	P
		RSS(K) = Repair level ratio (ratio)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P

(continued)

Table 3-4. (continued)

Cost Element	Equation	Cost Factor Description	Model Input (P) Primary (I) Intermediate
• Transportation and Packaging (continued)			
- Packaging Material	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times 2 \times W(K) \times RPM \times [1-RSS(K)] \times [1-DSC(K)]/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		W(K) = Weight of K^{th} item (lb)	P
		RPM = Packaging material cost ($/lb)	P
		RSS(K) = Repair level ratio (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
- Shipping	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times 2 \times W(K) \times RSR \times RW(K) \times [1-RSS(K)] \times [1-DSC(K)]/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		W(K) = Weight of K^{th} item (lb)	P
		RSR = Shipping cost ($/lb)	P
		RW(K) = Item packing weight ratio (shipping weight/unpacked weight)	P
		RSS(K) = Repair level ratio (ratio)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
• Preventive Maintenance			
- Labor	$\sum_{I=1}^{Y} N(I) \times \sum_{N=1}^{NM} OT \times LPM(N) \times RSL/NPM(N)$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
	where:	LPM(N) = Maintenance time of N^{th} type preventive maintenance action (hrs/equip/action	P
	N = Designator for a specific preventive maintenance type	RSL = O/I maintenance personnel pay rate ($/hr)	P
	NM = Number of preventive maintenance types	NPM(M) = Time between inspections of N^{th} preventive maintenance (hrs/action)	P
- Material	$\sum_{I=1}^{Y} N(I) \times \sum_{N=1}^{NM} OT \times MPM(N)/NPM(N)$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		MPM(N) = Material cost of N^{th} type preventive maintenance action ($/equip/action)	P
		NPM(N) = Time between inspections of N^{th} type preventive maintenance (hrs/action)	P

(continued)

Table 3-4. (continued)

Cost Element	Equation	Cost Factor Description	Model Input (P) Primary (I) Intermediate
• Overhaul			
- Labor	$\sum_{I=1}^{Y} NOH(I) \times OHL \times RSD$	NOH(I) = Prime equipment overhaul schedule (equip/yr)	P
		OHL = Overhaul maintenance time (hrs/equip)	P
		RSD = Depot maintenance pay rate ($/hr)	P
- Material	$\sum_{I=1}^{Y} NOH(I) \times OHM$	NOH(I) = Prime equipment overhaul schedule (equip/yr)	P
		OHM = Overhaul maintenance material cost ($/equip)	P
- Transportation	$\sum_{I=1}^{Y} NOH(I) \times OHT$	NOH(I) = Prime equipment overhaul schedule (equip/yr)	P
		OHT = Material shipping rate ($/equip)	P
• Support & Test Equipment Maintenance	$\sum_{I=1}^{Y} N(I) \times STES$	N(I) = Prime equipment inventory (equip/yr)	P
		STES = Recurring support cost of S&TE ($/prime equip)	P
• Facilities			
- Inventory Storage O/I Level	$\sum_{I=1}^{Y} ISSI(I) \times CSI$	ISSI(I) = O/I maintenance material storage space (sq/ft/yr)	P
		CSI = O/I maintenance space cost ($/sq/ft)	
Depot Level	$\sum_{I=1}^{Y} ISSD(I) \times CSD$	ISSD(I) = Depot maintenance material storage space ($/sq/ft)	P
		CSD = Depot maintenance space cost ($/sq/ft)	P
• Documentation Maintenance	$\sum_{I=1}^{Y} NP \times RDM(I)$	NP = Number of pages in a set of technical data (pages)	P
		RDM(I) = Technical data management costs ($/page)	P
• Supply Support			
- Replenishment Spares	$\sum_{I=1}^{Y} N(I) \times \sum_{K=1}^{NK} OT \times DC(K) \times QTY(K) \times CST(K) \times DSC(K)/[R(K) \times FR(I)]$	N(I) = Prime equipment inventory (equip/yr)	P
		OT = Prime equipment operating time (hrs/equip/yr)	P
		DC(K) = Duty cycle of K^{th} item (ratio)	P
		QTY(K) = Quantity of K^{th} item (qty/item)	P
		CST(K) = Unit cost of the K^{th} item ($/item)	P
		DSC(K) = Discard rate of K^{th} item (ratio)	P
		R(K) = Mean time between failures of the K^{th} item (hrs/failure)	P
		FR(I) = Reliability improvement/degradation factor (factor)	P
- Supply System Management	$\sum_{I=1}^{Y} [(NSNP + NSNS) \times ANM] + \sum_{I=1}^{Y} [(NAP + NAPS) \times AAM]$	NSNP = Number of new NSNs for prime equipment (NSN)	P
		NSNS = Number of new NSNs for S&TE equipment (NSN)	P
		ANM = Annual NSN maintenance costs ($/NSN)	P
		NAP = Number of APLs for prime equipment ($/APL)	P
		NAPS = Number of APLs for support and test equipment (APL)	P
		AAM Annual APL maintenance cost ($/APL)	P
• Training			
- Operator	$\sum_{I=1}^{Y} LO(I) \times RAM \times CTO$	LO(I) = Manning level of operating personnel (personnel/year)	P
		CTO = Operator training costs ($/student)	P
- O/I Level Maintenance	$\sum_{I=1}^{Y} LM(I) \times RAM \times CTM$	LM(I) = Manning level of O/I maintenance personnel (personnel/year)	P
		RAM = Personnel attrition rate (ratio)	P
		CTM = O/I maintenance personnel training cost ($/student)	P
- Depot Level Maintenance	$\sum_{I=1}^{Y} LP(I) \times RAP \times CTP$	LP(I) = Manning level of depot maintenance personnel (personnel/year)	P
		RAP = Personnel attrition rate (ratio)	P
		CTP = Depot maintenance personnel training cost ($/student)	P

3.5 STANDARDIZATION PROGRAM OVERHEAD

Cost associated with the standardization program that are a result of establishing, maintaining, and effecting increased standardization in new ship construction are considered to be program overhead costs. These are fixed annual expenses required to support the shipbuilding programs. Some of these are shown in the Government Program Management section of Table 3-3.

The cost model reflecting these standardization program overhead areas is presented in Table 3-5 by a series of equations for the various activity elements, the sum of which is a standardization program overhead equation. Also presented are the cost factor descriptors and dimensions. The primary and intermediate model inputs (cost factors) are identified in the right-hand column; the model output is the cost element shown in the left-hand column.

Table 3-5. STANDARDIZATION PROGRAM OVERHEAD (SPO)

Equation	Cost Factor Description	Model Input: P, Primary; I, Intermediate
$SPO = \left[\sum_{I=1}^{Y} PMSB(I) + \sum_{I=1}^{Y} PMSH(I) + \sum_{I=1}^{Y} PMNM(I) + \sum_{I=1}^{Y} PMSU(I) \right] / \sum_{I=1}^{Y} NCE(I)/Y$	PMSB(I) = Standardization branch overhead costs ($/yr)	P
	PMSH(I) = SHAPM preparation of standardization portion of contract ($/yr)	I
	PMNM(I) = NAVSEC MECHDIV preparation of SCL monitoring of new APLS ($/yr)	I
	PMSU(I) = SUPSHIP monitoring of shipyard standardization efforts ($/yr)	I
where I = Designator for a specific project year	LBB = SHAPM labor rate ($/hr)	P
	LBC = NAVSEC labor rate ($/hr)	
Y = Number of years covered by the cost analysis	LBE = SUPSHIP labor rate ($/hr)	P
$PMSH(I) = LBB \times HRB$	HRB = Number of hours (hr)	P
$PMNM(I) = LBC \times HRC$	HRC = Number of hours (hr)	P
$PMSU(I) = LBE \times HRD$	HRD = Number of hours (hr)	P
	NCE(I) = Number of C/Es per year (#/yr)	P

This cost model is maintained separately from the previously introduced cost model to allow the cost portion of the selection criteria for standard versus nonstandard C/Es to be treated separately.

The cost model presented in Table 3-5 will be used to calculate the cost of maintaining a standardization program on a per C/E basis independently of the C/E selected.

CHAPTER FOUR

STANDARDIZATION COST DATA INPUTS

4.1 CASE EXAMPLES

Cost data inputs to the standardization life-cycle-cost model developed in Chapter Three are dependent on the complexity and nature of the C/E under consideration. They are further dependent on both the specific component being compared and the level of effort conducted by the organization performing the work. It was noted that some tasks were performed by Navy personnel, shipbuilder personnel, or component vendor personnel. In some instances the effort was divided among the organizations. Representative examples of the cost to perform many of these tasks are presented in this chapter. In general, cost estimates were based on detailed Government-provided data. In some cases, however, the costs were informal estimates based on very small data samples.

The amount of work associated with processing a C/E varies with the complexity of the C/E and whether the C/E is standard or nonstandard, as reflected by the difference in tasks and the flow of work described in Chapter Three. It was necessary to identify C/Es with various levels of complexity to establish a dialogue with the organization working on the C/E. To identify categories of C/Es for evaluation, the Standard Components List (SCL) of October 1977 was reviewed and categorized. Four groups of standard HM&E component/equipments were developed by grouping similar items: (1) deck and hull machinery, (2) fluid systems, (3) refrigeration/heating systems, and (4) electrical systems.

These groups were then reviewed to determine which one would provide a representative sample of HM&E equipments for evaluation. The electrical systems group was selected because of its wide range of item complexity. The equipments were then sorted into four categories of increasing complexity. The number of line items in the basic equipment APL was used as the criterion for establishing the four categories. In all, 46 APLs were examined, and after review of their characteristics, 4 C/Es were selected (one from each of complexity categories A through D) as typical equipments. The diesel engine was then added, as complexity category E, to this grouping as an example of a yet more complex equipment. This decision was reached after agreement with NAVSEA 605B. The five selected C/Es are shown in Table 4-1 in increasing order of complexity. These were used as case examples in the study.

Table 4-1. CHARACTERISTICS SUMMARY OF THE FIVE TYPICAL C/Es					
Complexity Category (APL Line Item Range)	A (0-1)	B (2-6)	C (7-13)	D (14-50)	E (>50)
Component/Equipment Example	Motor, AC	Switch, Rotary	Starter Motor	Power Panel	Diesel Engine
Number of line items in basic APL	1	6	13	14	683
Number of supporting APLs in basic APL	0	0	0	1	19
Number of NSNs	1	1	3	5	175

4.2 DATA FOR CASE EXAMPLES

Data required as inputs to the cost model were collected for each equipment in the complexity categories through discussions with Navy and shipbuilder activities. These are shown in Table 4-2. Certain cost input data (1977 base year) were inflated over the 12-year life-cycle-cost evaluation period, using an inflation factor of 6 percent per year. These costs were then averaged over the same period to provide a single average cost value for input to the life-cycle-cost model.

Certain cost inputs are treated in this study as one-time costs for the first year of the analysis. These are (1) Government Program Management, (2) Prime Equipment Acquisition, and (3) APL/NSN entry into the supply system and Documentation Acquisition as part of the Initial Support Acquisition. For the study, it is assumed that only one C/E from each complexity category is procured and all associated actions are completed in the first year of the 12-year period. In these cases, Y = 1 for purposes of life-cycle-cost calculation.

4.2.1 Referenced Data

Development of the input data is addressed in the following paragraphs. Those costs which required interpretation of various related work efforts or composites of specific cost inputs are addressed in this section. Included is the rationale or source reference, as applicable, for the specific data values used.

4.2.1.1 AAM - Annual APL Maintenance Cost

Data are based on a 1968 cost of $4.21 per APL in NAVSECMECHDIV 6834A: CFC;tm 4120, Ser. 942, 3 September 1968. Escalating this cost to be a 1977 base value results in $7.11 per APL. This cost was then inflated over the 12-year evaluation period and averaged to obtain the annual APL maintenance cost of $10.00 per APL.

Table 4-2. INPUT DATA FOR STANDARDIZATION LIFE-CYCLE-COST MODEL

Cost Factor Description		Complexity Category (Standard C/E)					Complexity Category (Nonstandard C/E)					Data Source Notes*
		A	B	C	D	E	A	B	C	D	E	
AAM	= Annual APL maintenance cost ($/APL)	0	10	10	10	10	0	10	10	10	10	1,6,8
ACDP	= Number of average complexity drawing pages (PGS)	2	3	7	25	25	2	3	7	25	25	3
ACP	= Number of average complexity pages (PGS)	2	2	21	60	60	2	2	21	60	60	3
AHA	= Average shipyard labor rate ($/hr)	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	3
ANM	= Annual NSN maintenance cost ($/NSN)	308	308	308	308	308	308	308	308	308	308	1,6
ATU(I)	= Acquisition and installation costs of training aids ($)	0	0	0	0	0	0	0	0	0	206,000	2
CACD	= Cost per average complexity drawing page ($/PG)	0	0	0	0	0	61	61	61	61	61	1,9
CACP	= Cost per average complexity page ($/PG)	0	0	0	0	0	225	225	225	225	225	1,9
CHCD	= Cost per high complexity drawing page ($/PG)	0	0	0	0	0	83	83	83	83	83	1,9
CHCP	= Cost per high complexity page ($/PG)	0	0	0	0	0	371	371	371	371	371	1,9
CNP	= Cost to process each new NSN ($/NSN)	0	0	0	0	0	78.18	78.18	78.18	78.18	78.18	1,6,9
CP	= Reproduction and distribution costs ($/page/copy)	100	100	100	100	100	100	100	100	100	100	3
CPL	= Cost to process each APL line item ($/item)	0	0	0	0	0	12.64	12.64	12.64	12.64	12.64	1,9
CSD	= Depot maintenance space cost ($/sq. ft.)	5	5	5	5	5	5	5	5	5	5	3
CSI	= O/I maintenance space cost ($/sq. ft.)	5	5	5	5	5	5	5	5	5	5	3
CST(K)	= Unit cost of the K^{th} item ($/item)	206	275	63	7,357	603	206	275	63	7,357	603	2
CTI	= Instructor training cost ($/student)	0	0	0	0	30	0	0	0	0	30	3
CTM	= O/I maintenance personnel training cost ($/student)	0	0	0	0	200	0	0	0	0	200	3
CTO	= Operating personnel training costs ($/student)	0	0	0	0	200	0	0	0	0	200	3
CTP	= Depot maintenance personnel training cost ($/student)	0	0	0	0	200	0	0	0	0	200	3
CU	= Prime equipment procurement price ($/equip)	206	824	412	51,500	206,000	206	824	412	51,500	206,000	4(B,E); 3(A,C,D)
DC(K)	= Duty cycle of K^{th} item (ratio)	1	1	1	1	1	1	1	1	1	1	3
DSC(K)	= Discard rate of K^{th} item (ratio)	1	1	0.5	0.3	0.5	1	1	0.5	0.3	0.5	3
FDRT	= Required stockage time for depot repairable items (days)	0	30	30	30	30	0	30	30	30	30	3
FILS	= Required stockage time at O/I level for spares (days)	30	30	30	30	30	30	30	30	30	30	3
FIRT	= Required stockage time for O/I repairable items (days)	30	30	30	30	30	30	30	30	30	30	3
FM	= Repair material rate; percent of item cost (ratio)	100	33	16	14	0.29	100	33	16	14	0.29	3
FPST	= Procurement lead and safety stockage time for spares (days)	90	90	90	90	90	90	90	90	90	90	3
FR(I)	= Reliability improvement/degradation factor (factor)	1	1	1	1	1	1	1	1	1	1	7
HCDP	= Number of high complexity drawing pages (PGS)	0	1	3	25	25	0	1	3	25	25	3

*1 Referenced (see 4.2.1). 2 Estimated (see 4.2.2). 3 Estimated - no source. 4 Referenced - Navy sources. 5 Referenced - shipbuilder sources. 6 Includes inflation factor (see 4.2). 7 Study assumption. 8 Category A items not stocked (AAM = 0). 9 Assumes documentation already exists in Navy inventory for standard C/E.

(continued)

Table 4-2. (continued)

Cost Factor Description		Complexity Category (Standard C/E)					Complexity Category (Nonstandard C/E)					Data Source Notes*
		A	B	C	D	E	A	B	C	D	E	
HCP	= Number of high complexity pages (PGS)	0	0	14	40	40	0	0	14	40	40	3
HRG	= C/E selection evaluated by SHAPM (hrs)	0	0	0	0	0	0	0	1	1	1	4
HRH	= C/E selection evaluated by NAVSEC (hrs)	0	0	0	0	0	0	0	1	2	3	5
HRI	= C/E selection evaluated by SUPSHIP (hrs)	0	0	0	0	0	1	1	1	1	1	4
HRJ	= Documentation review by SUPSHIP (hrs)	0	0	0	0	0	1	1	3	5	20	4,9
HRK	= Documentation review by SHAPM (hrs)	0	0	0	0	0	0	0	0	1	1	4,9
HRM	= Approval of nonstandard parts by SUPSHIP (hrs)	0	0	0	0	0	0	0	0	0	0	3
HRN	= Review cost per APL ($/APL)	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	5 (1 hr/APL)
HRT	= Number of hours to review test documentation (hr/yr)	2	2	2	5	5	2	2	2	5	5	3
ISSD(I)	= Depot maintenance storage space (sq. ft.)	1	1	2	6	24	1	1	2	6	24	3
ISSI(I)	= O/I maintenance material storage space (sq. ft./yr)	1	1	2	6	24	1	1	2	6	24	3
K	= Designator for a specific spare/repair item	1	1	1	1	1	1	1	1	1	1	7
LBB	= SHAPM labor rate ($/hr)	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	2
LBC	= NAVSEC labor rate ($/hr)	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	2
LBE	= SUPSHIP labor rate ($/hr)	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46	2
LM(I)	= Manning level of O/I maintenance personnel (personnel/yr)	0	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	3
LO(I)	= Manning level of operating personnel (personnel/yr)	0.01	0.01	0.01	0.02	0.25	0.01	0.01	0.01	0.02	0.25	3
LP(I)	= Manning level of depot maintenance personnel (personnel/yr)	0	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	3
LPM(N)	= Maintenance time of N^{th} type PM action (hrs/equip/action)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3
LSD(K)	= Depot maintenance time to repair K^{th} item (hr/item)	0	0.5	0.5	1	3	0	0.5	0.5	1	3	3
LSI(K)	= O/I maintenance time to repair K^{th} item (hr/item)	0	0.5	0.5	1	3	0	0.5	0.5	1	3	3
LSO(K)	= O/I maintenance time to remove, replace K^{th} item (hr/item)	0.5	0.5	0.5	1	3	0.5	0.5	0.5	1	3	3
MPM(N)	= Material cost of the N^{th} type PM action ($/equip/action)	2	5	5	5	5	2	5	5	5	5	3
N	= Designator of a specific preventive maintenance type (#)	1	1	1	1	1	1	1	1	1	1	7
NAP	= Number of APLs for prime equipment (#)	1	1	1	2	20	1	1	1	2	20	4
NAPL	= Number of APL line items (#)	1	6	13	14	683	1	6	13	14	683	4
NAPS	= Number of APLs for support and test equipment (APL)	0	0	0	0	0	0	0	0	0	0	3
NC(I)	= Number of copies (copies/yr)	10-NC(1) →									→	3
NHB	= Shipyard reviews SCL (hrs)	1	1	1	1	1	1	1	1	1	1	5
NHC	= Shipyard evaluates interface drawings and prepares trade-offs for standard C/Es (hrs)	1	1	1	1	1	1	1	1	3	3	5

*1 Referenced (see 4.2.1). 2 Estimated (see 4.2.2). 3 Estimated - no source. 4 Referenced - Navy sources. 5 Referenced - shipbuilder sources. 6 Includes inflation factor (see 4.2). 7 Study assumption. *8 Category A items not stocked* (AAM = 0). 9 Assumes documentation already exists in Navy inventory for standard C/E.

(continued)

Table 4-2. (continued)

Cost Factor Description	Complexity Category (Standard C/E)					Complexity Category (Nonstandard C/E)					Data Source Notes*
	A	B	C	D	E	A	B	C	D	E	
NHF = Shipyard C/E justification by shipyard (hrs)	0	0	0	0	0	12	12	40	140	140	5
NHH = Shipyard incorporates standardization specifications in procurement specifications (hrs)	1	1	1	1	1	1	1	1	1	1	5
N(I) = Prime equipment inventory (equip/yr)	1	1	1	1	1	1	1	1	1	1	3
NK = Number of spare/repair items in an equipment (#)	1	6	13	14	683	1	6	13	14	683	4
NN(I) = Prime equipment annual acceptance schedule (equip/yr)	1-NN(1) →										3
NM = Number of preventive maintenance types (#)	1	1	1	1	1	1	1	1	1	1	3
NOH(I) = Prime equipment overhaul schedule (equip/yr)	0	0	**	†	††	0	0	**	†	††	3
NP = Number of pages in a set of technical data (pages)	3	3	35	100	500	3	3	35	100	500	3
NPM(N) = Time between inspection of N^{th} type PM (hrs/action)	50	100	50	100	100	50	100	50	100	100	3
NSNP = *Number of new NSNs of primary equipment (#)*	0	0	0	0	0	1	1	3	5	175	4,9
NSNS = Number of new NSNs of support and test equipment (#)	0	0	0	0	0	0	0	0	0	0	2,9
OHL = Overhaul maintenance time (hrs/equip)	0	70	70	96	1,500	0	70	70	96	1,500	3
OHM = Overhaul maintenance material cost ($/equip)	0	300	100	8,000	10,000	0	300	100	8,000	10,000	3
OHT = Material shipping rate ($/equip)	0	10	50	100	100	0	10	50	100	100	3
OT = Prime equipment annual operating time (hrs/equip/yr)	1,000	1,000	1,000	1,000	300	1,000	1,000	1,000	1,000	300	3
PAPL = Cost to prepare APL ($/APL)	0	0	0	0	0	3	3	3	3	3	1,9
PET = Number of items tested (items/yr)	0	0	0	0	0	1	1	1	1	1	3
PHS = Approval of nonstandard parts use by shipyard ($/part)	21.38	21.38	21.38	21.38	21.38	0	0	0	0	0	5 (1 hr/part)
PHT = Number of nonstandard parts (#)	0	0	0	0	0	0	0	0	0	0	3
PPC = Cost per page of test documentation ($/page)	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	3
PSS(I) = Production support and services cost ($/yr)	20	80	10	5,000	20,000	20	80	10	5,000	20,000	4
PTC = Cost of vendor tests ($)	20	80	40	5,000	20,000	20	80	40	5,000	20,000	4
PTI(I) = Number of instructor students (students/yr)	0	0	0	0	5	0	0	0	0	5	3,9
PTM(I) = Number of O/I maintenance students (students/yr)	0	0	0	0	0	0	0	0	0	20	3
PTO(I) = Number of operator students (students/yr)	0	0	0	0	0	0	0	0	0	20	3
PTP(I) = Number of depot maintenance students (students/yr)	0	0	0	0	20	0	0	0	0	20	3
QTY(K) = Quantity of K^{th} item (quantity/item)	1	1	1	1	1	1	1	1	1	1	3

*1 Referenced (see 4.2.1). 2 Estimated (see 4.2.2). 3 Estimated - no source. 4 Referenced - Navy sources. 5 Referenced - shipbuilder sources. 6 Includes inflation factor (see 4.2). 7 Study assumption. 8 Category A items not stocked (AAM = 0). 9 Assumes documentation already exists in Navy inventory for standard C/E.

**1 for I = 4,8,12; 0 otherwise

†1 for I = 6,12; 0 otherwise

††1 for I = 3,6,9,12; 0 otherwise

(continued)

Table 4-2. (continued)

Cost Factor Description		Complexity Category (Standard C/E)					Complexity Category (Nonstandard C/E)					Data Source Notes*
		A	B	C	D	E	A	B	C	D	E	
RAM	= Operator and O/I level maintenance personnel attrition rate (ratio)	0	0	0	0	0	0	0	0	0	0	3
RAP	= Depot level maintenance personnel attrition rate (ratio)	0	0	0	0	0	0	0	0	0	0	3
RDM	= Technical data management costs ($/page)	2	2	2	2	2	2	2	2	2	2	3
R(K)	= Mean time between failures for K^{th} item (hrs/failure)	500	2,601	935	5,045	6,538	500	2,601	935	5,045	6,538	2
RPL	= Packaging labor cost ($/#)	10	10	10	10	10	10	10	10	10	10	3
RPM	= Packaging material cost ($/lb)	2	2	2	2	2	2	2	2	2	2	3
RSD	= Depot maintenance pay rate ($/hr)	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	2
RSL	= O/I maintenance personnel pay rate ($/hr)	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	21.38	2
RSR	= Shipping cost ($/#)	5	5	5	5	5	5	5	5	5	5	3
RSS(K)	= Repair level ratio (ratio)	1	0.7	0.7	0.5	0.5	1	0.7	0.7	0.5	0.5	3
RW(K)	= Item packaging weight ratio (shipping wt/unpacked wt)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3
STE(I)	= Support and test equipment acquisition costs ($/yr)	0	0	0	0	0	0	0	0	0	0	2
STEM	= Support and test equipment initial support rate, percent of S&TE acquisition cost (ratio)	0	0	0	0	0	0	0	0	0	0	2
STES	= Recurring support cost of S&TE ($/prime equip)	0	0	0	0	0	0	0	0	0	0	2
TDP	= Number of pages of test documentation (pages/yr)	0	0	0	0	0	2	2	2	5	5	3
W(K)	= Weight of K^{th} item (#)	5	10	20	1,000	2,000	5	10	20	1,000	2,000	3
Y	= Number of years covered by life-cycle-cost analysis	12	12	12	12	12	12	12	12	12	12	7

*1 Referenced (see 4.2.1). 2 Estimated (see 4.2.2). 3 Estimated - no source. 4 Referenced - Navy sources. 5 Referenced - shipbuilder sources. 6 Includes inflation factor (see 4.2). 7 Study assumption. 8 Category A items not stocked (AAM = 0). 9 Assumes documentation already exists in Navy inventory for standard C/E.

4.2.1.2 ANM - Annual NSN Maintenance Cost

Data are based on an average cost of $184 established by a Defense Supply Agency study entitled "Compendium of ICP Management Information, Volume I, Management Data", November 1974. Escalating this cost to a 1977 base value results in $219 per NSN. This cost was then inflated over the 12-year evaluation period and averaged to obtain the annual NSN maintenance cost of $308 per NSN.

4.2.1.3 CACD/CHCD - Cost per Drawing Page

Data are based on discussions with NAVSEA 046. Information obtained indicated $38 per page for average-complexity equipments and $52 per page for high complexity equipments. This figure is a 1969 cost and includes preparation, review, and production costs associated with the drawing. Escalating these figures to a 1977 base value results in the following:

$61 per page - average complexity

$83 per page - high complexity

4.2.1.4 CACP/CHCP - Cost per Technical Manual Page

Data are based on discussions with NAVSEA 04. Information was obtained from NAVSEA 04 indicating a range of $141 per page for average complexity to $233 per page for high complexity. Escalating these 1969 costs to 1977 base values resulted in the following:

$225 per page - average complexity

$371 per page - high complexity

Other discussions resulted in a range of $240 to $500 per page depending on complexity. The lower numbers were used in calculating cost for technical manuals and thus may be somewhat conservative.

4.2.1.5 CNP - Processing Cost per NSN

The personnel processing the nonstandard C/E APL at the Ships Parts Control Center were interviewed to identify the time required, by labor grade, to complete the APL introduction. When a nonstandard C/E is introduced at SPCC, the effort to process each nonstandard part is $26.82. In addition to the SPCC processing, it is necessary to enter each new NSN into the Federal Catalog System and into the NSC that will stock the part. The cost to enter the NSN into the Federal Catalog System is $25.59, which is based on data in NAVSUP ltr. SUP04D4/4120-20, 18 June 1968. The NSC introductory cost of $8.13 was based on discussions with NAVSUP 01 personnel. Escalating the 1968 cost of $25.59 to a 1977 base value results in $43.23. The total entry cost (1977) for a new NSN is equivalent to the sum of these values, or $78.18 per NSN.

4.2.1.6 CPL - Processing Cost per APL Line Item

The introduction of an APL for a nonstandard C/E requires the personnel at SPCC to process each line item on the APL. The cost of this effort is \$12.64 per APL line item.

4.2.1.7 PAPL - Preparation Cost per APL

The processing of the basic APL document also requires additional effort, which is estimated to be \$3.00 per APL. This estimate is based on discussions with SPCC personnel.

4.2.2 Estimated Data

Where no specific information was obtainable during the investigation, values for inputs were obtained from engineering estimates. Calculations for estimated values where additional assumptions were required are described below.

4.2.2.1 CST(K) - Unit Cost of K^{th} Item

In estimating the cost of the procurement of the items comprising the C/E, it was assumed that if all the items were purchased as a lot, the price would be twice the actual C/E procurement cost. Assuming that the average cost of the K^{th} item is equal to the procurement cost of all the items divided by the quantity of items, the estimated cost of the K^{th} item, CST(K), is $\frac{2 \times CU}{NK}$.

4.2.2.2 CTI/CTM/CTO/CTP - Personnel Training Costs

The total of CTI/CTM/CTO/CTP is assumed to be 10 percent of the acquisition cost of the C/E and applies only to complexity category E.

4.2.2.3 FDRT/FIRT - Required Stockage Time

Category A items are assumed to be nonrepairable, and stockage at the depot or O/I level is not required.

4.2.2.4 LBB/LBC/LBE - Government Labor Rate

GS13 level (1977 base) as load salary of \$25.46 per hour is assumed.

4.2.2.5 NSNS - Support and Test Equipment New NSNs

Support and test equipment for nonstandard component/equipment is assumed to be the same as that required for standard equipment (i.e., no change in state of the art for prime C/E). In both cases, no additional equipment from that currently in inventory is assumed to be required.

4.2.2.6 R(K) - Mean Time Between Failures for k^{th} Item

Mean time between failures was calculated by assuming that all items comprising the prime C/E have the same failure rate and can be described by the Weibull distribution. Mean times between failures (MTBF) for the complexity categories are assumed as the following values: A-500 hours, B-1000 hours, C-250 hours, D-500 hours, E-250 hours.

$$\text{MTBF (item)} = \Theta_c = \hat{\alpha}^{-1/\beta}\,\Gamma\left(\frac{\beta+1}{\beta}\right)$$

$$\text{where } \hat{\alpha} = \frac{\left[\dfrac{\Theta_s}{\Gamma\left(\frac{\beta+1}{\beta}\right)}\right]^{-\beta}}{N}$$

$$\text{MTBF (item)} = \Theta_c = \left[\frac{\left[\dfrac{\Theta_s}{\Gamma\left(\frac{\beta+1}{\beta}\right)}\right]^{-\beta}}{N}\right]^{-1/\beta}\Gamma\left(\frac{\beta+1}{\beta}\right)$$

Θ_s = Prime C/E MTBF

N = Number of items within prime C/E

β = Shape parameter in Weibull distribution = 2 to introduce item wearout

$$\Gamma\left(\frac{\beta+1}{\beta}\right) = \Gamma(.15) = 0.88623$$

Therefore,

$$\text{MTBF (item)} = \Theta_c = \left[\frac{\left(\dfrac{\Theta_s}{0.88623}\right)^{-2}}{N}\right]^{-1/2}(0.88623)$$

$$= \frac{0.88623}{\left[\dfrac{1}{N\left[\dfrac{\Theta_s}{0.88623}\right]^2}\right]^{1/2}}$$

4.2.2.7 ATU(I) - Acquisition and Installation Costs of Training Aids

It is assumed that a C/E is required at the training site.

4.3 STANDARDIZATION PROGRAM OVERHEAD

Cost data inputs to the standardization program overhead model developed in Chapter Three are delineated in Table 4-3. The following cost elements are estimated on the basis of discussions with the activities noted in the model:

- PMSB - The standardization efforts in NAVSEA are managed by a member of the Standardization Branch who provides a full-time service, coordinating with and assisting the Ship Acquisition Project Manager (SHAPM), the Supervisor of Shipbuilding (SUPSHIP) and the Ship Parts Control Center (SPCC), including supervision of a standardization group at NAVSEC, Mechanicsburg, Pennsylvania.
- PMSH - The SHAPM will incur standardization program costs when preparing his contract for the shipbuilder. He is responsible for incorporating the standardization policy, procedures, and guidance in acquisition contracts under his cognizance. The actual cost of this effort in preparing the contract is relatively small. An estimated figure of 20 hours per year (HRB) for standardization program overhead-related efforts is assumed.
- PMNM - The standardization group at NAVSEC, Mechanicsburg, Pennsylvania, is responsible for developing and maintaining the Standard Components List (SCL) and for monitoring new APLs. This task has been budgeted at $80,000 to $100,000 per year.
- PMSU - Each SUPSHIP Office is responsible for seeing that the shipbuilder complies with the standardization program. This is accomplished by ensuring that the necessary documents and data are available and that the shipyard is using standard C/Es wherever possible. These tasks are performed in conjunction with their other duties, and the hours specifically devoted to standardization overhead were not identified. An estimate of 100 hours per year was assumed as a representative figure.
- NCE - The Mechanical and Electrical Equipment Standardization Profile, Active Fleet Statistics, APL Ship Application Distribution, 1977 was reviewed to determine the total number of active Fleet APLs. A total of 179,015 APLs was indicated as reflecting 100 percent of total active fleet APLs. This number is considered to be an average per year for purposes of this analysis based on the assumption of averaging effects of APLs being both deleted and introduced on a per-year basis.

Table 4-3. STANDARDIZATION PROGRAM OVERHEAD COST INPUTS		
Cost Factor Description	Value	Data Source Notes*
PMSB(I) = Standardization Branch overhead cost ($/yr)	75,000	1
PMNM(I) = NAVSEC MECHDIV preparation of SCL monitoring of new APLs ($/yr)	90,000	1
LBB = SHAPM labor rate ($/hr)	25.46	2
LBC = NAVSEC labor rate ($/hr)	25.46	2
LBE = SUPSHIP labor rate ($/hr)	25.46	2
HRB = Number of SHAPM hours (hr)	20	3
HRC = Number of NAVSEC hours (hr)		4
HRD = Number of SUPSHIP hours (hr)	100	3
NCE(I) = Number of C/Es per year (#/yr)	179,015	1

*1 Referenced - see 4.3. 2 Estimated - see 4.2.2.4.
3 Estimated - see 4.3. 4 Total cost provided instead.

4.4 COST DATA INPUTS

The cost data inputs presented in this chapter were based on reference material, discussions with personnel from cognizant activities involved with the standardization program process, or, where information was not available, on engineering estimates. These data inputs are considered valid for using the standardization life-cycle-cost model to illustrate the application on typical HM&E examples. The life-cycle-cost analyses and standardization program overhead costs are presented in Chapter Five.

CHAPTER FIVE

LIFE-CYCLE-COST ANALYSIS

5.1 LIFE-CYCLE-COST MODEL OUTPUTS

Life-cycle costs were calculated for the C/Es identified in Table 4-1. The cost model was exercised for both standard and nonstandard C/Es on the basis of complexity category. Model outputs were produced in five areas: Government Program Management, Prime Equipment Acquisition, Initial Support Acquisition, Supply Support, and Total Life-Cycle Cost. The results, shown in Table 5-1, are based on a 12-year life.

Table 5-1. OUTPUTS OF STANDARDIZATION LIFE-CYCLE-COST MODEL

Cost Element	Costs (in Dollars) by Complexity Category									
	Standard					Nonstandard				
	A	B	C	D	E	A	B	C	D	E
PMG	21	21	21	43	428	72	72	174	297	1,090
PEA	333	1,011	529	56,671	226,171	661	1,399	1,476	64,836	249,336
ISA	3,135	3,035	35,014	100,228	549,806	3,833	3,908	46,010	132,742	911,628
SUP	8,439	3,513	18,486	234,845	197,529	12,134	7,209	29,574	253,325	844,329
LCC	11,928	7,580	54,050	391,787	973,934	16,700	12,588	77,234	451,200	2,006,383

5.2 INTERPRETATION OF RESULTS

Life-cycle-costs for the nonstandard and standard C/Es are shown in Figure 5-1 to illustrate the contribution to the total life-cycle cost made by each of the four major cost elements. The Government Program Management (PMG) cost element contributed an averaged 0.1 percent for the standard C/E as compared with 0.3 percent for the nonstandard. Prime Equipment Acquisition (PEA) resulted in an averaged 10.96 percent for the standard C/E versus 7.97 percent for the nonstandard. In the case of Initial Support Acquisition (ISA), results showed 37.42 percent as compared with 37.68 percent. Support (SUP) element contributions to life-cycle cost indicated a percentage contribution for the standard as 46.3 compared with 53.29 for the nonstandard. Table 5-1 shows that for all nonstandard cases, all cost-element costs are greater for nonstandard then for standard.

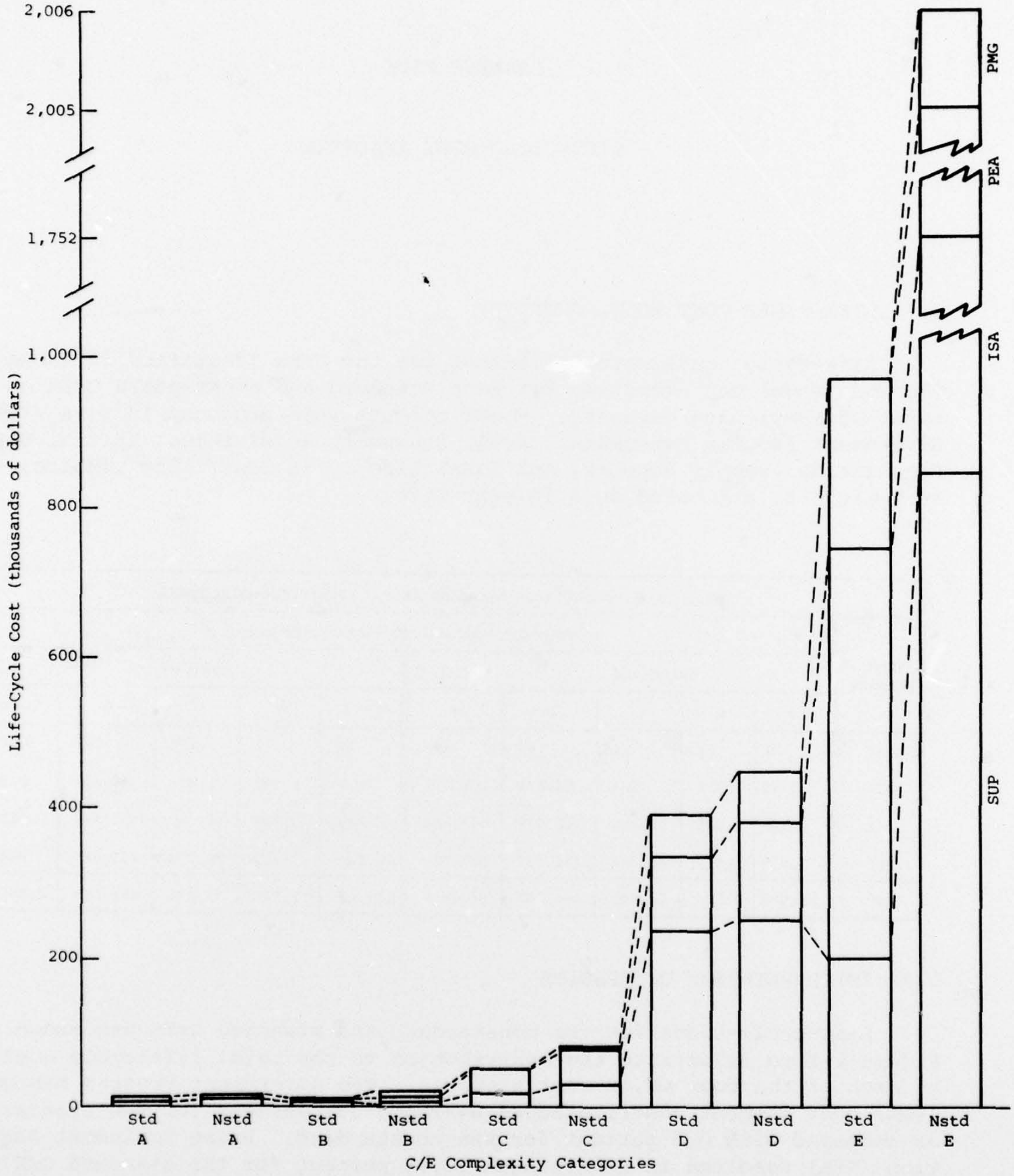


Figure 5-1. COST-ELEMENT CONTRIBUTION TO LCC

The contribution by cost element varied between complexity categories in a manner that did not permit determining a trend. This variation is principally due to the effects of differences in the prime equipment procurement price and the differences in cost of introducing the items into the Navy inventory.

The assumptions introduced in this analysis affect life-cycle-cost differences primarily because of the various complexity categories of C/Es -- that is, the effect of the maintenance and support of the equipments influenced the mean time between failures, operating time, corrective maintenance time, etc. Varying these parameters will affect the difference in life-cycle cost between complexity categories. A more descriptive cost difference could be obtained if the actual values of discrete C/Es were known. These data are required when the standardization life-cycle-cost model is used as a technique for selecting between two specific C/Es. For the purpose of this study, in determining differences between life-cycle costs of standard and nonstandard C/Es, equal values were assumed for similar standard and nonstandard C/Es.

5.3 COST-SENSITIVITY ANALYSIS

Cost model inputs have been analyzed to determine those influencing the difference in life-cycle cost between the nonstandard and standard C/E in the four major cost element areas. A cost-sensitivity analysis was performed to identify the effect that these cost estimates have on the life-cycle costs. Table 5-2 identifies the model inputs and shows the percent change in life-cycle cost if the input is varied by 10 percent.

The cost model inputs that resulted in a 1 percent or greater variation for at least three complexity categories were then varied in value by 25 percent. Table 5-3 identifies these values and shows the percent change in overall life-cycle cost.

The following cost inputs have the greatest effect on the life-cycle cost:

- Standard C/E
    - CP - Reproduction and distribution costs
    - CU - Prime equipment procurement price
    - FM - Repair material rate
    - NP - Number of pages in a set of technical data
    - OT - Prime equipment annual operating time
    - RSL - O/I maintenance personnel pay rate
- Nonstandard C/E
    - ANM - Annual NSN maintenance costs
    - CP - Reproduction and distribution costs

Table 5-2. COST SENSITIVITY - 10 PERCENT INPUT VARIATION										
Percentage Variations by Complexity Category										
Cost Inputs	Standard					Nonstandard				
	A	B	C	D	E	A	B	C	D	E
AAM		0.16	0.02	0.01	0.02		0.10	0.02		0.01
ACP						0.27	0.36	0.61	0.3	0.07
ACDP						0.07	0.14	0.06	0.03	0.01
AHA	0.09	0.15	0.02			0.22	0.29	0.12	0.07	0.02
ANM						2.21	2.94	1.44	0.41	3.22
CACD						0.07	0.14	0.06	0.03	0.01
CACP						0.27	0.36	0.61	0.3	0.07
CHCD							0.06	0.03	0.05	0.01
CHCP								0.67	0.33	0.07
CNP						0.07	0.06	0.03	0.01	0.10
CP	2.56	3.96	6.47	2.55	5.13	1.80	2.38	4.53		2.49
CPL						0.01	0.06	0.02		0.04
CSD	0.05	0.08	0.02	0.01	0.01	0.04	0.05	0.02	0.01	0.01
CSI	0.05	0.08	0.02	0.01	0.01	0.04	0.05	0.02	0.01	0.01
CTI					0.02					0.01
CTM										0.24
CTO										0.24
CTP					0.49					0.24
CU	0.17	1.08	0.08	1.31	2.11	0.12	0.65	0.05	1.14	1.03
FILS	0.03	0.01				0.02	0.01			
FM			1.2	4.38				0.84	3.8	
FPST	0.08	0.04				0.06	0.02			
HCDP							0.06	0.03	0.05	0.01
HCP								0.67	0.33	0.07
HRI						0.01	0.02			
HRJ						0.01	0.02	0.01		
HRN	0.02	0.03				0.01	0.02			
HRT	0.03	0.05	0.01			0.02	0.03	0.01		
LBE						0.03	0.04	0.01		
NAP	0.02	0.18	0.03	0.01	0.03	0.01	0.11	0.02	0.01	0.01
NAPL						0.01	0.06	0.02		0.04
NHB	0.02	0.03				0.01	0.02			
NHC	0.02	0.03				0.01	0.02			
NHF						0.15	0.21	0.11	0.07	0.01
NHH	0.02	0.03				0.01	0.02			
NP	2.57	4.05	6.63	2.61	5.26	1.84	2.44	4.64	2.27	2.55
NSNP						2.28	2.99	1.47	0.42	3.32
OHL			0.83	0.10	1.32			0.38	0.09	0.64
OHM			0.06	0.41	0.41			0.04	0.35	0.20
OHT			0.03	0.01				0.02		
OT	7.03	4.26	2.29	5.40	0.12	5.02	2.57	1.60	4.69	0.06
PET						0.01	0.06	0.01	0.11	0.10
PPC						0.03	0.04	0.01		
PTC						0.01	0.06	0.01	0.11	0.10
RPL			0.14	0.43	0.06			0.10	0.37	0.03
RPM			0.03	0.08	0.01			0.02	0.07	0.01
RSD			0.83	0.11	1.32			0.58	0.09	0.64
RSL	2.36	1.75	0.51	0.03		1.69	1.06	0.36	0.03	
RSR			0.11	0.32	0.04			0.08	0.28	0.02
TDP						0.03	0.04	0.01		0.06

	Table 5-3. COST SENSITIVITY - 25 PERCENT INPUT VARIATION									
Cost Inputs	Percentage Variations by Complexity Category									
	Standard					Nonstandard				
	A	B	C	D	E	A	B	C	D	E
ANM	--	0.00	0.00	0.00	0.00	5.53	7.34	3.59	1.02	8.06
CP	6.28	9.89	16.19	6.38	12.83	4.49	5.96	11.33	5.54	6.23
CU	0.42	2.72	0.19	3.29	5.29	0.31	1.64	0.13	2.85	2.57
FM	0.00	0.00	2.99	10.94	0.00	0.00	0.00	2.09	9.50	0.00
NP	6.44	10.13	16.58	6.53	13.14	4.60	6.10	11.60	5.67	6.38
NSNP	0.00	0.00	0.00	0.00	0.00	5.69	7.49	3.67	1.05	8.30
OHL	0.00	0.00	2.08	0.26	3.29	0.00	0.00	1.45	0.23	1.60
OT	17.56	10.67	5.72	13.49	0.30	12.54	6.43	4.00	11.71	0.14
RSL	5.91	4.39	1.27	0.09	0.01	4.22	2.65	0.89	0.07	0.01

- •• NP - Number of pages in a set of technical data
- •• NSNP - Number of new NSNs of primary equipment
- •• OT - Prime equipment annual operating time
- •• RSL - O/I maintenance personnel pay rate

As shown by the table, each cost input has a varying effect on life-cycle cost. This variation is dependent on whether the C/E is standard or nonstandard and which complexity category is being examined. Since the overall costs vary between standard and nonstandard, this effect of specific cost inputs having a greater percentage contribution to the totals is expected. For these reasons, a trend could not be determined. The cost sensitivity is only valid within each of the standard and nonstandard C/E groups and should not be used in comparison of the groups.

5.4 IMPACT OF STANDARDIZATION ON THE NAVY

The impact of standardization on the Navy can be measured as the life-cycle-cost savings from utilizing a standard C/E in lieu of a nonstandard C/E minus the standardization program overhead cost prorated per average number of active C/Es per year. The standardization program overhead costs, calculated over the 12-year period used for the standardization life-cycle-cost model, are identified in Table 5-4.

When prorated over the C/E population as shown, the overhead cost becomes significantly small in comparison with even the smallest life-cycle-cost savings identified in Table 5-1.

Table 5-4. STANDARDIZATION PROGRAM OVERHEAD COSTS (DOLLARS PER C/E)				
Standardization Branch (PMSB)	SHAPM (PMSH)	NAVSEC Mech Div (PMNM)	SUPSHIP (PMSU)	Standardization Program Overhead
7.06	0.05	8.48	0.24	15.83

An average cost saving to the Navy from the use of standard C/Es may be approximated as the cost saving per complexity category multiplied by the number of C/Es per complexity category on a per-ship basis. From Table 5-1, the saving per complexity category is approximately:

A - \$4,800

B - \$5,000

C - \$23,000

D - \$59,000

E - \$1,000,000

Assuming the worst case, in which only one C/E per complexity category is installed in a ship, the saving to the Navy achieved by invoking standardization is \$1,100,000 Since the population per ship would generally be greater, this cost is provided as the minimum saving per application.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The value of standardization of HM&E (hull, mechanical, and electrical) equipment to the Navy can be evaluated by determining the difference in life-cycle cost associated with introducing a new component/equipment (C/E) rather than using one that is already available and approved by the U.S. Navy. Determining the difference in life-cycle cost required calculations based on a complex function of many variables. Therefore, this study has developed a standardization life-cycle-cost model and life-cycle-cost estimating relationships and has identified the associated Navy standardization program tasks and documentation. Discussions with cognizant Navy offices indicate that this is the first detailed study of Navy standardization oriented to life-cycle cost.

The following conclusions were reached as a result of this study:

- Generally, on a life-cycle-cost basis, it costs more to introduce a new HM&E C/E than to use one already in the supply system.
- The following factors are associated with the cost of introducing nonstandard items:
  - Government Program Management costs provided the smallest contribution to the total life-cycle costs.
  - The operating time and maintenance philosophy for each C/E has a significant effect on the calculation of life-cycle cost for the standard C/E.
- The standardization life-cycle-cost model developed is limited in the area of cost of associated spares. It does not include the effects of existing inventory spares resulting from the standard C/E being already provisioned and supported. In the same manner, it does not address the relationship between C/E fleet population and required spares population.
- The recurring costs associated with item inventory control tend to become significant as they are incurred for each year of the C/E's life.

- The cost of introducing a nonstandard C/E into the supply system can be accurately determined only if the following data are obtained:
  - •• Difference in procurement cost for total order
  - •• Cost of all associated analyses
  - •• Cost of required support inventory
- The use and proper application of a standardization program can result in substantial cost savings. This study determined savings ranging from $4,800 for complexity category A to $1,000,000 for complexity category E. However, if not monitored closely, it can cause additional support problems. A standardization program will resist the introduction of new C/Es and consequently make it difficult to introduce improved C/Es. It can also tend to keep poorly performing items in the system unless reliability and maintainability factors are included in the selection process. Care must be taken to guard against the continuing support of inferior C/Es and the exclusion of improved equipment. The standardization program should be flexible enough to permit the use of a nonstandard C/E in those situations where it is the best choice in terms of cost, performance, supportability, and maintainability.
- Present standardization program procedures are not oriented to life-cycle cost.
  - •• Cost estimates are based only on the number of new NSNs introduced, which does not provide consistently accurate cost estimates.
  - •• Current contract clauses do not require that life-cycle costing procedures be used to assist in selecting C/Es.
  - •• Life-cycle-cost guidance is not available for selecting C/Es.

6.2 RECOMMENDATIONS

On the basis of the study conclusions, the following recommendations are offered:

- The incentive or penalty to the contractor associated with the introduction of a nonstandard C/E should not be based solely on the number of new NSNs in the APLs for the C/E or the percent of standard C/Es. It should be based on the life-cycle-cost difference between the nonstandard C/E and a standard C/E of identical form, fit, and function. This will allow the incentive or penalty to reflect the net increase or decrease in life-cycle cost to the Navy. It is therefore recommended that life-cycle costing be used in the selection process, and that it be contractually required.
- Decisions on the use of a specific standard or nonstandard C/E are made at the Shipyard/SUPSHIP level. It is important that the required level of information be provided to these activities to

allow them to make the best judgment in support of the actual shipbuilding contract requirements. It is recommended that specific life-cycle-cost guidance be provided at this level.

- Costs associated with establishing and maintaining a supporting inventory are strong contributors to the overall life-cycle-cost difference between nonstandard and standard C/Es. It is recommended that further study be conducted to evaluate the cost associated with establishing and monitoring a supporting inventory as part of the standardization life-cycle-cost model.

- Additional work is necessary to develop more sophisticated cost estimating relationships for the standardization life-cycle-cost model. Field experience with the model is required to mold it into a strong standardization-program tool. It is therefore recommended that further studies, including review of applications, be conducted to refine the standardization life-cycle-cost model to increase its effectiveness.

- This study evaluated the life-cycle-cost savings for HM&E equipments only. It is recommended that further studies be conducted to expand the application of the standardization life-cycle-cost model to other than HM&E equipments.